JOURNAL OF DAIRY SCIENCE

Contents

Standardizing the Babcock Test for Milk by Increasing the Volume of the Sample and Eliminating the Meniscus on the Fat Column. E. O. Herreid, L. H. Burgwald, B. L. Herrington and E. L. Jack 685

A Study of the Cavitation Effect in the Homogenization of Dairy Products. C. C. Loo, W. L. Slatter and R. W. Powell 692

A Micromethod for Routine Determinations of Fat in Skimmilk and Nonfat Dry Milk Solids. Burdet Heinemann and M. Robert Rohr 703

The Nutritive Value of Alfalfa Hay. IV. Beet Pulp, Corn Gluten Meal and Soybean Oil Meal as Supplements to an All-alfalfa Hay Ration for Milk Production. C. F. Huffman and C. W. Duncan 710

Predictability of Breeding Efficiency in Dairy Cattle. Durward Olds and D. M. Seath 721

Studies on Growth and Survival of Calves Fed Semi-synthetic Milks from Birth. Joe Kastelic, Orville G. Bentley and Paul H. Phillips 725

Fertility of Diluted Bull Semen Containing 100 Micrograms of Streptomycin Per Milliliter. H. L. Easterbrooks, P. Heller, W. N. Plastridge, E. L. Jungherr and F. L. Elliott 737

The Effectiveness of Some Antifoaming Agents in the Condensing of Skimmilk and Whey. J. Robert Brunner 741

The Effects of Feeding Parathion to Dairy Cows. Paul A. Dahm, F. C. Fountaine, J. E. Pankaskie, Roger C. Smith and F. W. Atkeson 747

Milk Fever (Parturient Paresis) in Dairy Cows—A Review. J. W. Hibbs 758

Abstracts of Literature A133

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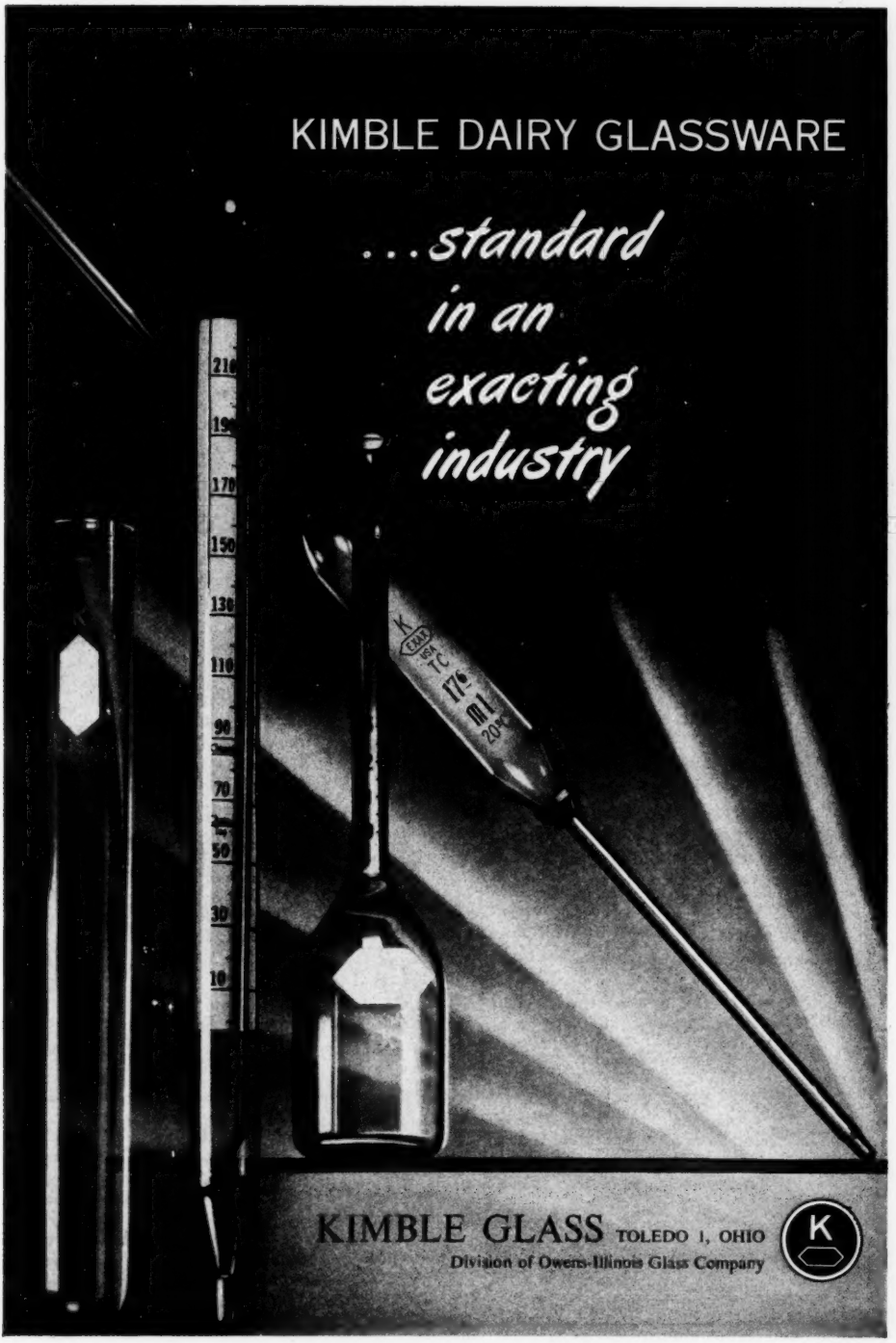

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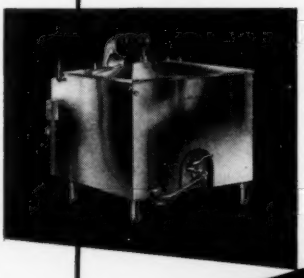

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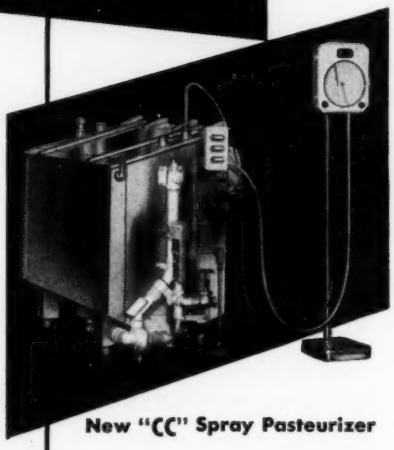

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JOURNAL OF DAIRY SCIENCE

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STANDARDIZING THE BABCOCK TEST FOR MILK BY INCREASING THE VOLUME OF THE SAMPLE AND ELIMINATING THE MENISCUS ON THE FAT COLUMN

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Illinois, Ohio, New York and California Agricultural Experiment Stations, respectively

The Babcock test has been used in the dairy industry for nearly 60 yr. During this period of time, there have been no significant refinements in conducting the test, except for more accurate glassware and improved heated centrifuges.

When Babcock (2) contributed his test to the dairy industry, it was sufficiently accurate for most practical purposes; in fact, he did not claim a high degree of accuracy for his test. As the industry became specialized, emphasis was placed on improving the efficiency of dairy plants by more carefully accounting for milk fat in milk and cream purchased and in processed and manufactured products. It is the opinion of students of testing problems that the Babcock method can be made more accurate and thereby be more useful in accounting for milk fat in dairy plants. For this reason a subcommittee was appointed in the American Dairy Science Association to study methods for refining the method, without sacrificing its simplicity and usefulness.

A number of investigators (7) have determined the accuracy of the Babcock method by comparing it with the ether extraction method which is the standard for comparison. The earlier comparisons agreed closely, but those made in recent years show that the Babcock method yields results from 0.05 to 0.07 per cent higher than those obtained with the Roese-Gottlieb method or its mechanized modification, the Mojonnier method.

Investigators in experiment stations and technicians in commercial laboratories have recognized that the upper meniscus on the fat column is a variable factor in reading the Babcock test for fat in milk. Babcock (2) stated that the lowest and the highest limits of the fat column should be included in the reading and this meant that (3) the reading should be taken at a point where the upper surface of the fat meets the side of the graduated neck and not from the dark line caused by the refraction of the curved surface. For the past 30 yr. this method of reading the Babcock test has been stated by the Association of Official Agricultural Chemists in its Official and Tentative Methods of Analysis (1). Dahlberg (5) and Herreid *et al.* (10) have emphasized the difficulty of determining the exact point at which the fat meets the wall of the graduated neck. Babcock included the meniscus in the fat reading in order to obtain closer

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[1] Chairman and members, respectively, of Subcommittee in the Manufacturing Section of the American Dairy Science Association, to Standardize the Babcock Test for milk fat to agree with the Mojonnier method.

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agreement with the ether extraction method and it has been shown (4, 6, 8) that some fat remains in the bulb of the test bottle and is not collected in the graduated neck during the centrifuging process. Including the meniscus compensates for this residual fat.

Evidently the Babcock test yields results that are higher than those obtained with the ether extraction method and the meniscus on the fat column makes it difficult for different technicians to obtain consistent results with the present technique of reading fat tests of milk.

PROCEDURE

The Committee decided that the simplest approach to standardizing the Babcock test in order to obtain agreement with the ether extraction method was to increase the volume of the sample of milk and eliminate the meniscus on the fat column. Letters were sent to a number of prominent leaders in the dairy industry to obtain their opinions concerning this method. There was practically unanimous agreement that this is a sound and practical procedure.

TABLE 1

Reading Babcock fat tests of unpreserved milk with and without the meniscus and comparing them with the Mojonnier method

Station	No. of samples	Method				
		Babcock			Mojonnier	Difference[a]
		With meniscus	Less meniscus	Meniscus		
		(%)	(%)	(%)	(%)	(%)
Ohio	81	4.35	4.21	0.14	4.30	−0.09
Illinois	44	4.16	4.01	0.15	4.09	−0.08
Vermont	88	4.26	4.12	0.14	4.20	−0.08

[a] Between Mojonnier and Babcock less meniscus.

The first step was to determine how much the elimination of the meniscus would reduce the Babcock test for milk as compared to the Mojonnier method. This was accomplished by determining the fat content of a number of samples of unpreserved milk with the Babcock method and reading the tests with and without the meniscus. After the fat tests were read by the regular Babcock method, the bottles again were placed in the water bath for 5 min. and they were read immediaely after the meniscus had been eliminated with glymol. When the meniscus is eliminated, the results from three experiment stations in table 1 indicate that the Babcock test for milk is reduced on the average by slightly more than 0.08 per cent below the Mojonnier method. Therefore, to get both methods to agree, it will be necessary to increase the weight of the milk samples for the Babcock method by an amount equivalent to 0.08 per cent. Assuming that the milk contains 4 per cent of milk fat, the sample should be increased by 0.36 g., $\left(\frac{0.08}{4} \times 18 = 0.36\right)$ making a total weight of 18.36 g. of milk which must be delivered by the pipette.

To determine the amount of milk that might adhere to the pipette, samples were heated to 35 to 36° C. and pipetted into milk test bottles with 18.05 ml. pipettes which had been weighed. The pipettes were allowed to drain for 10 to 15 sec. after free outflow had ceased and the milk in the tip was blown out. They were again weighed to obtain the net weight of milk in each one. The average weight of milk retained by 36 pipettes was 0.13 g., varying from 0.10 to 0.15 g. Consequently, the total weight of milk required for the modified Babcock test is 18.49 g. $(18.36 + 0.13 = 18.49)$ for milk containing 4 per cent of milk fat.

Since the capacity of the pipette that will contain 18.49 g. of milk must be known, specific gravity determinations were made on 62 samples of unpreserved milk. The average specific gravity at 35 to 36° C. was 1.025. Consequently, the capacity of the pipette should be 18.05 ml. $(18.49 \div 1.025 = 18.04)$. A temperature of 35 to 36° C. was used because preserved composite samples are prepared and pipetted at 35 to 38° C. Therefore, unpreserved milk also should be sampled in this same temperature range.

Increasing the sample by a constant weight of 0.36 g. is not proportional to the fat content of all milk because it is based on the approximate fat percentages of the experimental samples. It is evident that there is a slight bias in favor of the lower testing milks and a slight bias against the higher testing ones, (table 2)

TABLE 2

The calculated effect on tests of milk of different fat percentages by increasing the weight of the sample 0.36 g.

Milk fat	Calculated size of sample	Volume of sample at 35–36° C. sp. gr. 1.025[a]	Calculated error
(%)	(*g.*)	(*ml.*)	(%)
5.00	18.29	17.97	−0.014
4.00	18.36	18.04	0 000
3.85	18.37	18.05	0.000
3.45	18.42	18.10	+0.017
3.25	18.44	18.12	+0.025

[a] Includes 0.13 g. of milk which, on the average, adhered to pipette.

as indicated by theoretical calculations. The error, however, is small and would probably not be measurable in the great majority of cases with the present milk test bottle.

On the basis of the aforementioned preliminary work, the following procedure for the modified Babcock method was adopted for experimental work by the committee: (a) heat preserved and unpreserved milk samples at 35 to 38° C.; (b) mix thoroughly by pouring milk from one container to another three to four times; (c) fill 18.05 ml. pipette so that the upper surface of the milk is at the graduated mark on the draw tube; (d) drain pipette into test bottle for 10 to 15 sec. after free outflow has ceased and blow out last milk in the tip. Cool samples to 20° C. before adding acid; (e) have H_2SO_4 (sp. gr., 1.82–1.83 at 20° C.) at 20 to 22° C. The amount required will vary from 15 to 17 ml., depending on its strength; (f) proceed as in the original Babcock method; (g) add 2 drops

of a colored mineral oil (glymol, sp. gr. not to exceed 0.85 at 20° C.) as each bottle is taken from the water bath at 57.3 to 60° C. The oil must flow down the sides of the neck and not be dropped onto the fat. Measure the fat from the bottom of the column to the fat-glymol line.

The Mojonnier method was used as the standard for comparison and variations for the modified Babcock method indicated as plus or minus. It was conducted as follows: (a) heat milk samples to 35 to 38° C.; (b) mix thoroughly by pouring from one container to another three to four times; (c) weigh the charge of milk directly into tared extraction flask (9); (d) proceed as in the regular Mojonnier method (11).

The different collaborators calibrated their own pipettes, except in some cases the pipettes were calibrated in an experiment station laboratory. The collaborators obtained their own samples for analysis. Replicate samples of milk were not sent to the different collaborators because it is practically impossible to ship samples of preserved milk without destabilizing the fat emulsion. The collaborators represented experiment station and dairy plant control laboratories and state and federal regulatory laboratories. Some collaborators were suggested by the Association of Official Agricultural Chemists.

EXPERIMENTAL

The results of comparisons of the modified Babcock method with the Mojonnier method by 14 collaborators on 232 samples of unpreserved milk are shown in table 3. In addition, five collaborators also submitted results for the regular Babcock method. The results submitted by collaborators A to E inclusive, on a total of 135 samples of milk show close agreement for the modified Babcock and Mojonnier methods. With the exception of collaborator J, who made 27 comparisons, the data from the others are insufficient from which to draw conclusions as to their ability to obtain accurate results with the modified Babcock method. Four collaborators mentioned their inexperience with the Babcock method as probably being responsible for the wide variations which they obtained between both methods.

The results of comparisons by five collaborators of the modified Babcock with the Mojonnier method on 66 samples of preserved milk also are shown in table 3. Collaborators B and D obtained close agreement between both methods on 26 samples of milk, while collaborators C, I and K reported mean variations of -0.03, $+0.04$ and -0.10 per cent, respectively. The standard deviations of the differences between the modified Babcock and Mojonnier methods did not exceed 0.05 per cent for collaborators A to E, inclusive, and they did not exceed 0.1 per cent for any of the other collaborators.

The data submitted by some of the collaborators emphasizes the necessity of standardizing the Babcock method so that it will yield satisfactory agreement with the Mojonnier method. For example, for the regular Babcock and Mojonnier methods on nonpreserved milk, collaborator A obtained a mean difference of $+0.08$ per cent, collaborator F a mean difference of $+0.06$ per cent and collaborator I a mean difference of -0.02 per cent.

TABLE 3

A comparison of the results obtained with the Babcock, the modified Babcock and the Mojonnier methods on samples of nonpreserved and preserved milk by different collaborators

Collaborator	No. of trials	Regular Babcock	Modified Babcock	Mojonnier	Difference[a] mean	S.D.
		(%)	(%)	(%)	(%)	(%)
			Nonpreserved			
A	37	3.58	3.49	3.50	−0.01	0.05
B	24	.....	4.22	4.21	+0.01	0.02
C	24	.....	3.58	3.59	−0.01	0.03
D	20	.....	4.08	4.07	+0.01	0.02
E	30	.....	4.13	4.12	+0.01	0.01
F	12	4.20	4.17	4.14	+0.03	0.02
G	6	.....	4.24	4.22	+0.02	0.04
H	8	.....	3.78	3.76	+0.02	0.01
I	11	3.83	3.81	3.85	−0.04	0.06
J	27	.....	4.70	4.74	−0.04	0.06
K	12	.....	3.81	3.89	−0.08	0.04
L	6	4.00	3.90	4.01	−0.11	0.02
M	9	.....	3.73	3.71	+0.02	0.03
N	6	3.97	3.94	3.95	−0.01	0.05
			Preserved			
B	16	.....	4.20	4.20	0.00	0.03
C	24	.....	4.82	4.85	−0.03	0.05
D	10	4.00	3.97	3.98	+0.01	0.05
I	5	3.96	3.94	3.90	+0.04	0.01
K	11	.....	3.71	3.81	−0.10	0.07

[a] Between modified Babcock and Mojonnier methods.

DISCUSSION

The results submitted by collaborators A to E, inclusive, on a total of 135 samples of unpreserved milk indicate that the modified Babcock method is accurate. These collaborators were all experienced laboratory technicians. The data from the other nine collaborators, with the exception of collaborator J, are insufficient to prove their ability to obtain accurate results with the modified method.

In the present Babcock test the inclusion of the meniscus is somewhat empirical, that is to include partially void space as part of the fat column in order to compensate for fat, some of which adheres to the walls and shoulder of the test bottle and some of which is probably suspended and dissolved in the acid solution. In the modified Babcock test this empirical value is substituted, in part, with another in that the volume of the sample is increased to compensate for the amount that removal of the meniscus lowers the Babcock test on the average below the Mojonnier method. The chief disadvantage of the modified Babcock test is that it is more difficult to explain the reason for the specified capacity of 0.18 g. (2 ml.) of fat for each per cent on the graduated neck of the test bottle because the weight of the sample of milk is increased from 18 to 18.36 g.

For the most part official methods have lagged in improving testing techniques. This is not intended as a criticism of those responsible for the official methods; in fact, the dairy industry has not requested from the Association of Official Agricultural Chemists more refined techniques for testing milk and milk

products. For example, Official and Tentative Methods of Analysis (1) specifies a sampling temperature of 15 to 20° C. for milk and if lumps of cream are not dispersed, the sample should be warmed to about 38° C., mixed thoroughly and finally cooled to 20° C. before pipetting. The way composite samples are kept in most plants at the present time it is necessary to heat them to about 38° C. to obtain a homogeneous mixture. Cooling the samples back to 20° C. is very apt to result in partial churning of the fat emulsion when they are mixed immediately before being pipetted into test bottles. Consequently, the fat tests of partially churned samples are lowered because clusters of fat adhere to the inner surface of the pipette.

Since it is necessary to heat preserved composite samples at 35 to 38° C. in order to prepare and pipette them accurately, obviously the same technique should be used for unpreserved milk samples. It is not possible to account for fat in dairy plants as accurately when milk purchased is sampled and pipetted at one temperature and when it is sold these techniques are performed at a different temperature. Nevertheless, this is being done where milk is purchased on the basis of the fat content of preserved composites and is sold on the basis of the fat content of unpreserved samples.

In comparing the accuracy of the modified Babcock with the Mojonnier method, it should be recognized that the fatty materials are chemically different and the procedures for estimating them are radically different for each method. In the Babcock method milk fat is released from its emulsion in normal milk by the drastic action of a strong acid and is finally removed from the acid solution by adding water and centrifuging. During its contact with the acid solution, the fat undergoes some chemical changes whereby free fatty acids are formed and possibly some of the fat is sulfonated and water is adsorbed. On the other hand, the solvents used in the Mojonnier method for normal milk extract milk fat without changing it chemically. However, in addition to milk fat a portion of the phospholipids, chiefly lecithin also is extracted. Consequently, fat estimations made by the Mojonnier method are slightly higher than they should be, but the errors are small for milk because the phospholipids are reported to average about 0.04 per cent and not all of them are extracted by the Mojonnier method.

The suggested revisions for the modified Babcock method are simple and fundamentally sound. Only the pipettes will have to be changed and regulatory officials in each state could have them recalibrated. The use of glymol is the only added technique and it has been an accepted part of the Babcock test for cream for about 35 yr.

SUMMARY

Standardizing the Babcock test for milk by increasing the volume of the sample and eliminating the meniscus on the fat column is simple, fundamentally sound and accurate as indicated by comparisons with the Mojonnier method on 135 samples of unpreserved milk by five experienced laboratory technicians. It is the judgment of the Committee that the modified Babcock method is better than the method now in use.

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A STUDY OF THE CAVITATION EFFECT IN THE HOMOGENIZATION OF DAIRY PRODUCTS[1, 2]

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The homogenizer has been in use for more than 50 yr. Various theories have been advanced to explain the phenomenon of homogenization. Impingement has been discussed as a factor in homogenization by Doan and Minster (4), Sommer (19), Doan (5), Farrall (6) and Tracy (21). Explosion of fat globules due to sudden change in pressure was discussed by Farrall (6) and Tracy (21). Shearing of fat globules by layers of liquid travelling at different velocities at the valve clearance was discussed as a responsible factor of homogenization by Sommer (19), Farrall (6) and Tracy (21). The doubtful nature of these theories was discussed by Sommer (20) in 1946.

Conventional homogenizers are so constructed that the product attains a very high velocity on flowing through the homogenizer valve. From hydraulic principles it can be expected that there will be a corresponding drop in pressure at the sharp entrance to the valve clearance. Should the pressure drop to the value of the vapor pressure, vapor cavities will form in the flow giving rise to the phenomenon known as "cavitation." The destructive effect of cavitation (10, 11, 12, 13, 14, 15) suggests that it might be a very important factor in homogenization. In fact, cavitation has been demonstrated to be responsible for the production of an emulsion of two immiscible liquids by intense sonic vibration by various authors, notably Gaines (8), Chambers (1, 2) and Sollner (16, 17). Therefore, it seemed that the cavitation effect might be a possible factor in the homogenization of dairy products. A study of its role in homogenization should aid in explaining the mechanism of this process.

EXPERIMENTAL PROCEDURE

A hydraulical analysis of the flow through a Cherry-Burrell 125 viscolizer valve was conducted to determine whether cavitation would occur. Mathematical expressions of the relationships between the valve clearance were derived. Such theoretical relationships were checked by actual measurement of the corresponding valve clearance and applied pressure from which the lowest pressure at the valve clearance was calculated. The original valve was modified to show the effect of cavitation in the homogenization process. The original and the modified valves are shown diagrammatically in fig. 1.

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The following modifications were made to reduce the applicability of the prevailing theories of homogenization: (a) Most of the sections which tend to create shearing were cut away; (b) the wall surrounding the valve was made at a greater distance from the valve clearance and inclined at an angle to the stream to reduce the intensity of collisions of the fat globules on the wall.

The relationship of the valve clearance and applied pressure also was determined experimentally for the modified valve. Calculations based on these experimental values were made to ascertain whether cavitation would occur in this valve.

The original valve and the modified valve were used to homogenize four lots of milk and one lot of cream of varying fat content. Milk was pasteurized at 143° F. for 30 min. and then homogenized at $140 \pm 2°$ F. The cream was pasteurized at 158° F. for 30 min. and homogenized at that temperature. The milk or cream was homogenized at pressure intervals of about 300 lb. from

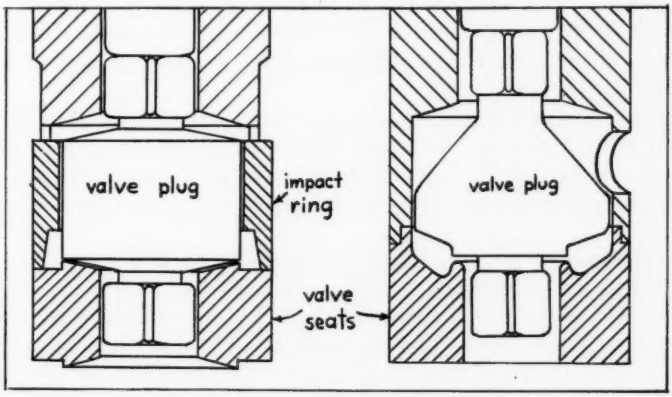

FIG. 1. Cross-sectional views of the Cherry-Burrell 125 viscolizer valve assembly (left) and the modified valve assembly (right) used in the investigation.

0 to 2500 lb. per in.^{2} Three methods were used to measure the degree of homogenization of milk, namely, the microscopic measurement of fat globule size, the determination of the United States Public Health Service (U.S.P.H.S.) index (22) and a specially developed centrifugal pipette method. The latter method determines the equivalent specific surface area of the fat phase. Only the microscopic and the centrifugal pipette methods were used on cream.

In the microscopic method, glycerine was used as part of the diluent as was used by Farrall *et al.* (7). The fat globules were stained with Nile blue sulphate, as suggested by Cole and Smith (3). The microscope used was equipped with a 15x eyepiece, a 90x objective and a micrometer of 200 divisions to 1 cm. The micrometer was calibrated to read 0.65 μ per division. Fat globules were classified according to size. The first class included fat globules less than 1.5 μ and other classes were established at 1 μ levels, *i.e.*, 1.5–2.5, 2.5–3.5, etc. About 160 to 170 globules from widely scattered fields were considered

sufficient to yield representative results. Since stability of a dispersion is mainly a surface effect, the roots of the mean square of the diameters of the globules were calculated to indicate degree of homogenization.

In determining the U.S.P.H.S. index of the degree of homogenization, the storage temperature used was 40° F. A siphon which had one leg long enough to reach the bottom of the quart bottle was used to determine the fat content. Mixing of milk and acid for 3 to 5 min. with a mechanical shaker assured clear fat columns.

The centrifugal pipette method was developed to give numerical indication of the degree of homogenization over a wide range. The principles underlying this method were to increase the rate of globule migration by means of centrifugal force and to obtain a more nearly representative sample of the top layer by setting a special pipette in the sample at a certain depth during the entire centrifuging period. Knowing the average fat test of the sample and that of the top layer after centrifuging, the rate of fat globule migration could be calculated. Neglecting the effects of emulsification and electrical charges, the equivalent specific surface area of the fat phase (square centimeters per gram fat) could be determined.

The apparatus used in the centrifugal pipette method include 20×150 mm.-test tubes with a line etched at 1.6 cm. from the top, special pipettes, numbered and tared (see fig. 2a), special pipette holders for weighing the pipettes (see fig. 2b), Babcock centrifuge (deep pocket type), and Mojonnier testing equipment.

The procedure of the centrifugal pipette method is as follows: (a) Fill the test tube with well mixed milk sample to about the level mark at 1.6 cm. from the top. (b) Adjust the temperature to 70° F. by immersion in water bath for about 5 to 7 min. (c) Place the pipette into the test tube and adjust the level of milk to the level mark. (d) Centrifuge in a Babcock centrifuge for exactly 8.5 min. Previous to use, the interior temperature of the centrifuge also should be adjusted to about 70° F. (e) Remove the pipette with its contents as follows: First, stop the short end of the pipette with the thumb of one hand while the other hand holds the test tube. Invert the whole system gently, pouring the milk from the test tube while keeping the pipette stopped at the short end. Then withdraw the pipette downward, using care so as not to touch it on the wall of the test tube which may carry a heavy cream layer. (f) Keep the pipette in a tilted position, allowing the milk inside the pipette to subside slightly toward the bend but not so much as to reach the thumb stopping the hole. Wipe the outside clean with cheese cloth. If the outside of the pipette is coated heavily with cream, it may be washed carefully under a warm water tap and then wiped clean and dry. (g) Use the special pipette holder to weigh the pipette and milk on an analytical balance. Drain the milk into a Mojonnier extraction flask. Rinse out the pipette three to four times with about 0.5 ml. distilled water at a time. A medicine dropper is helpful for rinsing. (h) Add water to the extraction flask to make up the volume to 10 ml. and then proceed according to the method of testing milk

on a Mojonnier tester. (i) In expressing the results, let the per cent fat migrated out of the lower 8 cm.-portion in the test tube during the 8.5 min. be designated as the centrifugal pipette method index I_{cp}; the test of the milk in the pipette, F_t; and the average test of the original milk, F. Then

$$I_{cp} = \frac{5.4\ (F_t - F)}{8\ F} \times 100$$

By applying Stokes' law, the equivalent diameter of the fat globules can be calculated and from this value the equivalent specific surface area may be obtained.

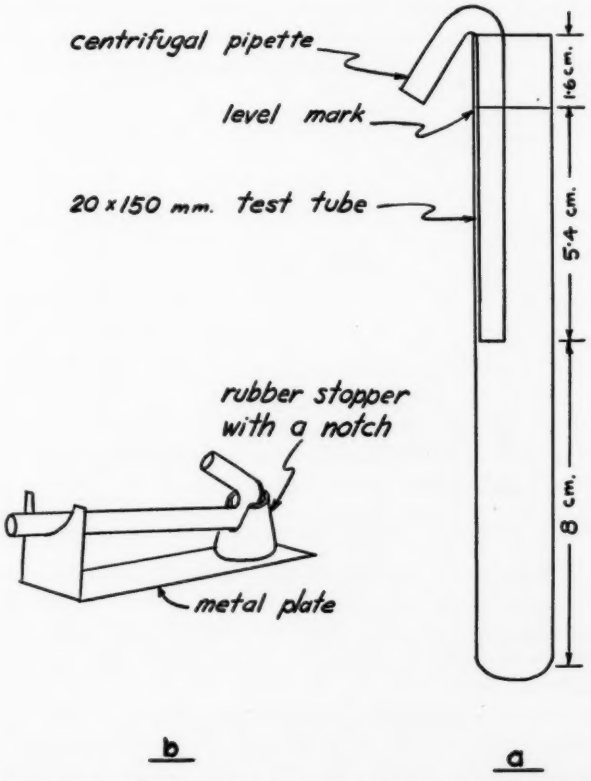

FIG. 2. The centrifugal pipette and the special test tube (a) and the pipette holder (b) used in the centrifugal pipette method of determining the degree of homogenization.

The equivalent specific surface area = $1.11 \times 10^5\ (I_{cp})^{-1}$ cm.^{2} per g. For products of which the continuous phase has specific gravities and viscosities different from skimmilk, the above formula for the equivalent specific surface area should be modified accordingly. The formula was plotted on charts for quick conversion operation.

The U.S.P.H.S. index I_{PH}, the equivalent specific surface area of the fat phase and the root-mean-square diameter of the fat globules were plotted against applied pressure on separate graphs. From the graphs, the pressures at which an $I_{PH} = 10$, or an equivalent specific surface area of 4×10^4 cm.^{2} per g. (this arbitrary value of equivalent specific surface area was found to correspond satisfactorily to well homogenized milk) could be determined for both values. The reciprocals of these pressures were used to represent the mechanical efficiencies of the valves for the purpose of comparing their performances.

RESULTS

The determination of the occurrence of cavitation phenomenon in homogenization. A diagrammatical view of the Cherry-Burrell 125 viscolizer valve

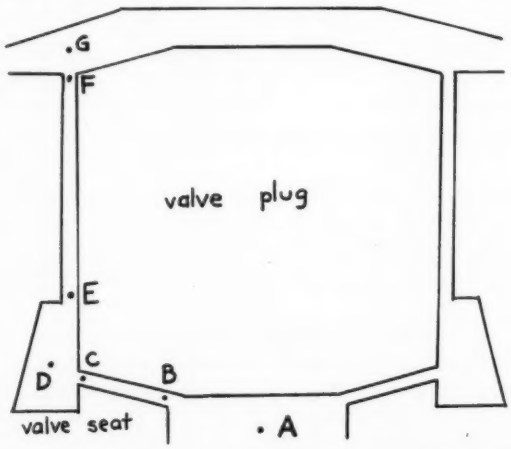

FIG. 3. Simplified diagram of the Cherry-Burrell 125 viscolizer valve.

assembly is shown in fig. 3. The flow between B and C was found to be turbulent while that between E and F was found to be in the critical range between turbulent and laminar when ice cream mix was used. The following expressions were derived to represent the relationship between the applied pressure and the valve clearance:

When the flow was assumed laminar between E and F,

$$P_A = 417r^{-3} + 328r^{-2} + 212.9 \text{ lb./in.}^2 \quad \text{Eq. 1}$$

P_A = applied pressure; r = one half of the valve clearance in thousandths of an inch. When the flow was assumed turbulent between E and F,

$$P_A = 417r^{-3} + 328r^{-2} + 272.0 \text{ lb./in.}^2 \quad \text{Eq. 2}$$

The lowest pressure that would occur in the flow was found to be at the vena contracta (the contraction of the flow at a sudden constriction in the passage) at the entrance of the valve clearance. It could be calculated from the following equation:

$$P_{vc} = P_A - 1198.3r^{-2} \text{ lb./in.}^2 \quad \text{Eq. 3}$$

From equations 1, 2 and 3, it could be seen that a turbulent flow from *E* to *F* would give the pressure at the vena contracta at the valve clearance a higher value than would be obtained by laminar flow. Theoretically, if the higher value would decrease to the vapor pressure of the ice cream mix when the applied pressure was at a value less than normal homogenization pressure, cavitation should occur during homogenization. Therefore, equation 1 was eliminated and only equations 2 and 3 were used to represent the relationship between valve clearance, applied pressure and the pressure at the vena contracta at the valve clearance. Curves 2 and 3 in fig. 4 are equations 2 and 3 plotted with pressure against valve clearance. These curves indicate that the pressure at the vena contracta dropped to the vapor pressure of the ice cream mix when the homogenizing pressure was at about 540 lb. per in.^{2} Theoretically, then, these calculations suggest that cavitation should occur in the original valve.

The equations for skimmilk and water also were derived and are presented below:

For skimmilk:

$$P_A = 4 - 2r^{-3} + 316r^{-2} + 153 \text{ lb./in.}^2 \quad \text{Eq. 4}$$

$$P_{vc} = P_A - 1150r^{-2} \text{ lb./in.}^2 \quad \text{Eq. 5}$$

For water:

$$P_A = 387r^{-3} + 304r^{-2} + 142 \text{ lb./in.}^2 \quad \text{Eq. 6}$$

$$P_{vc} = P_A - 1110r^{-2} \text{ lb./in.}^2 \quad \text{Eq. 7}$$

Water and skimmilk were used to determine experimentally the relationship between valve clearance and applied pressure for the original valve. The results are plotted in fig. 4 together with the theoretical valve clearance-applied pressure curves. The experimental curves follow the theoretical curves closely except at the lower pressures. By putting a series of experimental values of the applied pressure and the valve clearance into equations 5 and 7, it was found that the pressure at the vena contracta at the valve clearance tended to decrease to zero at an applied pressure of about 900 lb. per in.^{2} when skimmilk was used and at an applied pressure of about 700 lb. per in.^{2} when water was used. These experimental results also suggest that cavitation should occur in the original valve.

The relationship between the valve clearance and applied pressure for the modified valve was determined using milk. The results are plotted in fig. 4 as curve 8. Applying Bernoulli's equation to the flow at the valve clearance, it was found that the pressure at the valve clearance tended to drop to zero when the applied pressure reached 200 lb. per in.^{2} Therefore, cavitation also should occur in the modified valve at higher pressures.

Comparison of the performances of the modified and the original valves. The typical curves showing the performances of the modified and the original valves as determined by the centrifugal pipette method, the U.S.P.H.S. index method and the microscopic method are shown in fig. 5. Those curves obtained by means of the centrifugal pipette method and the U.S.P.H.S. index method showed distinct differences between the performances of the two valves and permitted easy determination of the ratio between their mechanical efficiencies. Those curves

obtained by means of the microscopic measurement of globule size revealed only slightly greater reduction in the globule size by the modified valve. The curves became level rapidly to the right, hence it was difficult to determine the ratio between the mechanical efficiencies of the two valves by the microscopic method.

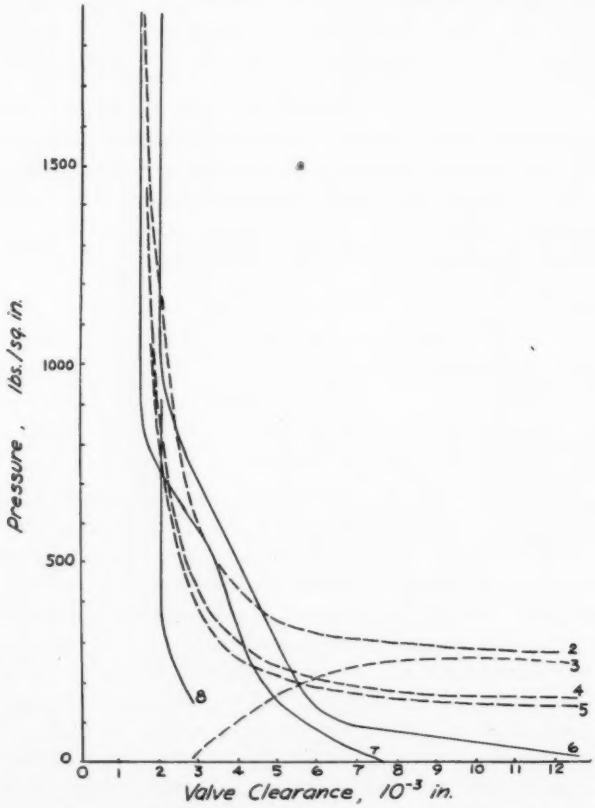

FIG. 4. Curves showing the relationship between applied pressure, the pressure at the vena contracta at the valve clearance and the valve clearance. Curve 2—the theoretical curve of applied pressure *vs.* valve clearance of the original valve using ice cream mix. Curve 3—the theoretical curve of the pressure at the vena contracta at the valve clearance *vs.* valve clearance of the original valve using ice cream mix. Curves 4 and 5—the theoretical curves of the applied pressure *vs.* valve clearance of the original valve using skimmilk and water, respectively. Curves 6 and 7—the experimental curves of the applied pressure *vs.* valve clearance of the original valve using skimmilk and water, respectively. Curve 8—the experimental curve of the applied pressure *vs.* valve clearance of the modified valve using milk.

Table 1 presents the ratio of the mechanical efficiencies of the modified and the original valves from four trials of milk and one trial of cream, as determined by the centrifugal pipette method and the U.S.P.H.S. index method. The centrifugal

pipette method revealed 27 to 85 per cent higher mechanical efficiency in the modified valve, while the U.S.P.H.S. index method revealed 6 to 47 per cent higher efficiencies in the modified valve. Hence, the modified valve was found to produce the same degree of homogenization at lower pressures than required with the original valve.

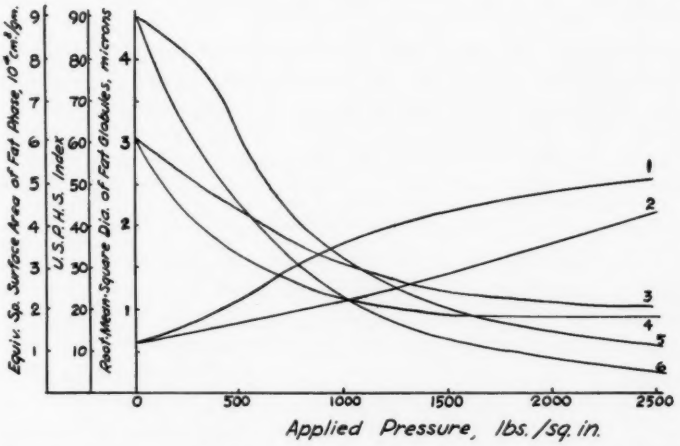

FIG. 5. Typical curves showing the performances of the original and the modified valves. Curves 1 and 2—curves of the modified and the original valves, respectively, as determined by the centrifugal pipette method (equivalent specific surface area of the fat phase *vs.* applied pressure). Curves 3 and 4—curves of the original and the modified valves, respectively, as determined by the microscopic method (root-mean-square diameter of the fat globules *vs.* applied pressure). Curves 5 and 6—curves of the original and the modified valves, respectively, as determined by the U.S.P.H.S. index (U.S.P.H.S. index *vs.* applied pressure).

DISCUSSION

The experimentally determined relationship of the valve clearance and the applied pressure agreed favorably with the theoretical values, as may be seen in fig. 4. The relatively large disagreement between the theoretical and the experimental curves at lower pressures probably was due to the fact that the pressure gauge was primarily made to read accurately at normal homogenization pressures and not for pressures as low as 500 lb. per in.^{2} or less.

The valve clearance measurements showed that at normal homogenization pressures the valve clearance of both valves would be approximately 0.002 in., which was about ten times as large as the average diameter of fat globules in unhomogenized products.

In discussing the explosion theory, Sommer (20) pointed out that the low compressibility of the liquids rendered the occurrence of explosion doubtful. This reason appears inadequate in itself, for a liquid may change into a vapor state which is capable of expanding or contracting rapidly. This is supported by the phenomenon of "rebound" of vapor bubbles observed by Knapp and Hollander

(9). However, an explosion due to change of physical state is not likely to occur in milk fat, because the serum phase which has a much higher vapor pressure will change state first and, thus maintain the pressure at a rather constant level.

The wall surrounding the valve slit of the modified valve was designed to incline at an angle to the emerging stream and at a distance farther away than in the original valve, and yet the modified valve showed a higher mechanical efficiency.

Both theoretical and experimental results obtained using the original valve indicated that cavitation should occur in the flow when the homogenizer was working at normal homogenization pressures. Calculations based on actual meas-

TABLE 1

Comparisons of the performances of the modified and the original valves as determined by the centrifugal pipette method and the U. S. P. H. S. index

Trial no.	Product	Fat test of the product	$\frac{\text{Mech. eff. of the orig. valve}}{\text{Mech. eff. of the mod. valve}}$ As determined by	
			Cent. pipette method	U. S. P. H. S. index
		(%)		
1	milk	3.82	$\frac{100}{183}$	$\frac{100}{147}$
2	milk	4.59	$\frac{100}{141}$	$\frac{100}{119}$
3	milk	4.47	$\frac{100}{138}$	$\frac{100}{113}$
4	milk	4.07	$\frac{100}{127}$	$\frac{100}{106}$
5	cream	20.29	$\frac{100}{185}$	.....

urements of valve clearance of the modified valve also indicated the occurrence of cavitation when this valve was used. Sufficiently large Reynold's numbers indicating turbulent flow were obtained for the original valve.

The results obtained from valve performance comparisons indicated that the modified valve had higher mechanical efficiency than the original valve. The higher mechanical efficiency of the modified valve seemed to indicate that cavitation might be one of the important factors of homogenization, for the modified valve was designed in such a way as to reduce the applicability of the prevailing theories of homogenization and to bring about a definite cavitation phenomenon.

When an homogenizer is being operated, a sudden development of a hissing noise occurs when the pressure rises to a certain value. Such a hissing noise has been described by Sollner (18) and Kornfeld and Suvorov (10) as an indication of cavitation phenomenon in a flow.

The role of cavitation in the homogenization process may be suggested as follows: When the product reaches the vena contracta at the valve clearance the

pressure drops to the vapor pressure of the product due to the tremendous gain in velocity. At this point cavitation begins. The numerous cavities, most of which develop at the fat-serum interfaces, are swept into a region where the pressure becomes higher due to either enlargement of the flow passage or pressure waves created by the collapse of other cavities. Here the vapor phase can no longer exist and the cavities collapse instantaneously, resulting in numerous blows that shatter the fat globules. Also, the instantaneous formation of cavities may cause numerous spots of dehydration which in turn cause local temporary increase in acidity and the collapse of the cavities produces high frequency pressure waves, shock and local development of heat. This suggests that cavitation also might be involved in other phenomena related to homogenization, such as viscosity change, curd tension reduction, fat clumping, antioxidation effect, denaturation of the proteins, etc.

CONCLUSIONS

The analysis of the flow of liquids through a homogenizer valve assembly indicated that cavitation should occur during normal homogenization operations.

An homogenizer valve modified to produce cavitation and to reduce the applicability of some of the prevailing homogenization theories had a higher mechanical efficiency than the original valve.

Cavitation has been suggested as one of the important factors responsible for the homogenization of dairy products.

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A MICROMETHOD FOR ROUTINE DETERMINATIONS OF FAT IN SKIMMMILK AND NONFAT DRY MILK SOLIDS

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While modifications of the Babcock test have been used successfully for testing buttermilk and whey, no satisfactory Babcock test has been published for testing skimmilk for fat. The modification using butyl alcohol presents the most consistent results. However, these results, even when obtained from the most careful analysis, still are as little as one-tenth of the amount of fat measured by the Mojonnier method. If, for example, a Babcock result is 0.01 per cent, the Mojonnier method may result in 0.05 to 0.10 per cent fat. Therefore, processing losses may vary as much as 100 per cent without detection by the Babcock test. The Mojonnier method, while measuring all of the fatty extract, takes about 45 min. to run and hence, is not suitable for a routine control test.

In order to have a suitable control test, a nephelometric determination (2) was developed. This method required about 20 min. to complete and the accuracy was satisfactory. However, further studies resulted in a method based on the work of Jones (3). He showed that a method could be employed to measure the quantity of fat in an ether solution by the area of its monolayer formed on a water-sulphuric acid film with a surface tension of 20 dynes per square centimeter. This method was found to yield results in 12 min.—about the same length of time involved in a Babcock test.

APPARATUS AND MATERIALS

Ultramicro-pipettes. Two types of pipettes are satisfactory for use. The Kirk pipette is commercially available.[1] These were graduated to contain 0.0075 ml. If the pipette is graduated "to contain," it must be rinsed at least twice with pure petroleum ether, placing the rinsings in the center of the spread. For routine use, however, pipettes were prepared from Breed and Brew pipettes by drawing the tip to about 1 or 2 mm. Some care must be exercised in the drawing process. The bore should not be small enough to allow the mercury to separate. The pipette may be calibrated with mercury on a "to contain" basis. It also may be calibrated with benzyl benzoate on a "to deliver basis." The work reported below was done with a pipette calibrated to deliver 0.0072 ml. Several pipettes have been made and calibrated with benzyl benzoate ranging from 0.0072 to 0.0081 ml. and all found suitable from the standpoint of accuracy. In use, a rubber or plastic hose about 1 ft. long is attached to the end of the pipette opposite the tip for convenience in drawing in the sample and expelling it. The pipette is rinsed in pure petroleum ether before and after each use.

Dish. An 8-in. pyrex pie dish is painted on the inside bottom with black asphalt paint or black enamel. The dish then is coated on the inside with a thin

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[1] Microchemical Specialities Co., Berkeley 3, Calif.

layer of hard paraffin. According to Harkins (1) the paraffin prevents contamination of the acid solution by metallic ions dissolved from the glass. Under routine conditions, and using pyrex glass, this error, if any, is negligible. Continued use of oil gradually dissolves the paraffin on the rim of the dish. For these reasons and for the purpose of this test, sufficient melted paraffin is poured on the inside bottom of the dish to completely cover the paint. The sides and rim are left uncoated. The prepared dish is placed on a leveling table $9'' \times 9''$ equipped with three leveling screws. The leveling table, in turn, is placed in a tray $10'' \times 14'' \times 1.5''$ deep.

Tracing glass. The edges of a pane of single strength glass about $14'' \times 20''$ are taped with adhesive tape to allow safe handling. (Transparent plexiglass is not satisfactory.) The tracing glass is laid on the edges of the $10'' \times 14'' \times 1.5''$ tray and the leveling screws of the leveling table adjusted so that the edges of the pie plate are separated from the tracing glass by about $0.25''$. This distance should be as small as possible to prevent parallax, yet not close enough for the surface of the acid solution to accidentally contact the glass while tracing.

Light source. A $12'' \times 12''$ sheet of white opaque plexiglass or heavy white cardboard is positioned almost parallel to and directly above the tray. The height is adjusted to clear the head of the observer. A spotlight (150 watt) is placed to the rear of the tray and directed toward the sheet of white plexiglass. Adjustments are made in the light and reflector until the observer, by leaning over the dish filled with acid solution, may see a uniform white reflection from the white sheet above him.

Tuberculin syringe. A 1-ml. tuberculin syringe is fitted with a no. 27 hypodermic needle. The point of the needle is rounded off. The syringe is filled with prepared oil and the tip of the needle held to the surface of the acid solution in the center of the dish. As the piston is very slowly compressed, the oil spreads over the surface with a play of colors. The first color is a brown-gold, followed in turn by purple, blue, green, yellow and red, as first order colors. With the continued addition of oil, the spectrum is completed again as second order colors. Further addition of oil causes the colors to proceed into their third order. When the third order green appears, the addition of oil is stopped and the surface is ready for the deposition of the measured quantity of ether solution of the fatty extract.

Acid solution. While Jones (3) specified the use of 0.3 per cent H_2SO_4, a 0.2 per cent solution of glacial acetic acid in distilled water was found preferable. The acid is less corrosive and the colors formed during the deposition of the prepared oil are more easily discerned. Another advantage is that the deposition of oil may be stopped and started without forming clearly defined colors, while this is not the case with H_2SO_4.

Oil. Jones specified any good grade of lubricating oil which had been oxidized by heating at 300° C. for 8 hr. On several oils heated in this manner, tarry residues were obtained which did not spread. The oil used was heated at 300° F. and air bubbled through during the heating period. At intervals of 0.5 hr., a portion was removed and cooled. This portion was tested for its ability to spread. The oil

used was heated under these conditions for 1.5 hr. However, it was found that each oil must be standardized to yield areas having a factor of 0.9 γ of fatty extract per square inch.

Planimeter. Two different planimeters were used in this study. It appears that any planimeter reading in square inches with an accuracy of 0.02 in.^{2} would be satisfactory.

Parchment paper. After the spread is made, the tracing glass is placed over it and the outlines of the spread traced with a china marking pencil having a sharp point. Parchment paper (as used for wrapping butter) or any thin tracing paper is placed over the tracing glass and the area copied to the paper. The paper then is tacked on a drawing board and the area measured with a planimeter.

Other equipment. Torsion balance, 10 mg. sensitivity; hot plate; 4 oz. oil sample bottles, tall form; tared Mojonnier fat dishes with lid having a $\frac{3}{8}$" hole near one edge; 10" × 2" double strength glass slide; two 25-ml. Machlett pipettes. The Machlett pipettes must have well fitted stop cocks which require no lubricant. No lubricant has been found which may be safely used. Use of the Silicone "greases" produce an uncontrolled error due to their high solubility in ether.

METHOD

Weigh or pipette 4.00 g. of skimmilk into a 4-oz. oil bottle or Mojonnier fat extraction tube. For nonfat dry milk solids weight 4.00 g., transfer to a 100-ml. volumetric flask, shake gently to avoid foam and make to the mark with distilled water. Transfer 10 ml. of this solution to the oil bottle or extraction tube. Add 6 ml. of water to the skimmilk and add no water to the nonfat dry milk solids. Then, add 1.5 ml. concentrated NH_4OH and shake. Add 10 ml. ethyl alcohol and shake. Using Machlett pipettes, add 25 ml. of ethyl and 25 ml. of petroleum ether, shaking 1 min. after each addition. Allow to stand or centrifuge until the layers have separated. Using a 25-ml. volumetric pipette (which has a rubber stopper on the delivery end to prevent too deep an insertion of the tip into the ether layer), transfer 25 ml. to a Mojonnier fat dish and evaporate to dryness. Cool the pan in water and wipe dry with a clean towel. Cover the pan with an aluminum lid containing a hole large enough to insert a pipette. Place on a Torsion balance and balance. (A butter moisture balance is convenient). Place 2.5 g. on one side and add petroleum ether in slight excess—about 4.1 ml. Rotate the cup, holding it lightly in the fingers so as to avoid transfer of body heat.

At this point, prepare the surface of the acid solution by passing the glass slide across the surface three or four times, wiping the edge of the slide with a clean towel after each passage. The temperature of the solution should be between 20 to 30° C. When the surface shows only a few streaks of gold-brown color, it is sufficiently clean to start the addition of oil. After the third order green color is reached, return to the pan on the Torsion balance, add additional petroleum ether to bring the weight to 2.50 g., quickly rotate, insert pipette and withdraw the volume to be spread. Bring the ether solution exactly to the mark on the pipette. Hold the tip of the pipette at the surface and expel the solution

gently, blowing the last drop under the surface. (If a "to contain" pipette is used, it is necessary to rinse it twice with pure petroleum ether at this point transferring the rinsings to the center of the spread. This results in a more irregular figure, making tracing errors larger. A "to contain" pipette may be calibrated more accurately, however.)

The tracing glass then is placed over the surface and the outlines of the figure traced on the glass. This figure is, in turn, traced on parchment paper and the area measured with a planimeter. For routine work, three tracings are made from the figure on the surface, their areas averaged and the fat computed from the average.

The formula used for computation for skimmilk is:

$$\frac{(\text{aliquot})\ (\gamma/\text{in.}^2)\ (\text{area})\ (\text{ml. ether solution})}{(\text{ml. spread})\ (\text{wt. sample in grams})\ (10^4)} =$$

$$\frac{(2)\ (0.90)\ (\text{area})\ (3.94)}{(0.0072)\ (4)\ (10^4)} = (\text{area})\cdot(0.0246) = \text{per cent fat}$$

The value of the aliquot is 2 since 25 ml. of the combined petroleum and ethyl ether were removed from a total of 50 added to the sample. The value of $\gamma/\text{in.}^2$ was determined experimentally as outlined below. According to the literature, this value varies with the nature of the fatty substance spread. The specific gravity of the petroleum ether was determined to be 0.635 at 21° C. Since 2.50 g. were used, this is equivalent to 3.94 ml. The pipette used was found to deliver 0.0072 ml. and the weight of the sample for skimmilk was 4 g. In the case of nonfat dry milk solids, the sample weight is 0.4 g. and the calculation of the per cent fat from the area then becomes:

$$(\text{area})\cdot(0.246) = \text{per cent fat}$$

RESULTS

Determination of $\gamma/\text{in.}^2$. The data are limited geographically and seasonally. A total of 32 samples of fatty extract obtained from the Mojonnier test of fresh skimmilk, buttermilk, whole milk and butter during January, February and March was examined. The fatty material was dissolved in petroleum ether to give solutions containing from 0.4 to 5.5 mg. per ml. A 0.0072 aliquot was spread and the area measured. The factor was determined as follows:

$$\frac{(1000 \times \text{mg./ml.})\ (0.0072)}{\text{area in in.}^2} = \gamma/\text{in.}^2$$

The mean was 0.90 and the standard deviation was $\pm$ 0.07. There was no significant difference among the fats from the dairy products examined. This is somewhat surprising, since buttermilk contains the highest percentage of phospholipids which are surface active.

Recovery. The method of extraction is the same as reported previously in connection with a nephelometric method for determining fat in skimmilk (2). However, further checks were made by testing the same sample for fat eight times using the above method. Eight 4-g. aliquots of the same sample also were extracted by the standard Mojonnier method adding 5 g. of ether to the dried fatty extract (to compensate for twice as much fatty residue in the pan) and

spreading a 0.0072-ml. portion. The average area of the eight portions extracted once and a 25-ml. aliquot of the ether extract taken was 3.25 in.^{2} with a standard deviation of $\pm$ 0.11. The average area of the eight portions extracted twice and the ether decanted to the cup was 3.24 in.^{2} with a standard deviation of $\pm$ 0.08.

Precision of the proposed method. When the same sample of skimmilk was tested eight times under ideal conditions by one of the authors, the coefficient of variation was found to be 2.95 per cent. The other author obtained a value of 2.67 per cent.

Comparison between the standard Mojonnier method and proposed method for skimmilk. Forty-nine random samples of skimmilk were tested individually by both methods. The mean per cent fat as obtained by the Mojonnier test was 0.0837. The mean per cent fat as obtained by the proposed method was 0.0824. The range in fat by the Mojonnier test was 0.060 per cent to 0.165 per cent. The standard error of the difference between tests was $\pm$ 0.012 per cent.

Comparison between the standard Mojonnier method and proposed method for nonfat dry milk solids. Eighteen random samples ranging from 0.66 to 1.35 per cent were tested individually by both methods. The Mojonnier test averaged 1.06 per cent while the proposed method averaged 1.050 per cent. The standard error of the difference between methods was $\pm$ 0.124 per cent.

Comparison between the standard Mojonnier method and proposed method for nonfat dry milk solids under routine conditions. Various members of the laboratory staff made standard Mojonnier tests on nonfat dry milk solids. The same individual usually did not make both the Mojonnier and the proposed test on the same samples. Samples were not tested in duplicate. Twenty-two samples were compared. The average per cent fat by the Mojonnier was 0.927 and by the proposed method was 0.897 per cent. The standard error of the difference between tests was $\pm$ 0.104. These samples ranged from 0.78 per cent to 1.13 per cent fat by the Mojonnier method.

DISCUSSION

The largest single error in the proposed method (hereafter referred to as the "drop test") occurs when the outline of the spread is traced to the tracing glass. The coefficient of variation calculated from tracing the same spread eight times is about 2.5 per cent. In order to reduce this error, the spread is traced three or more times and the average area taken. The next important source of error is in the preparation of the surface for the spread. When a second order green color was used, the coefficient of variation of eight spreads was found to be 10.9 per cent, while with a third order green color, the coefficient of variation was 2.5 per cent. While a few oils other than oxidized lubricating were tried, none was found superior. Temperature of the acid solution apparently is not a factor as long as it is between 20 and 30° C. The concentration of acid likewise does not appear to be important as long as it is about 0.2 per cent. Acetic and sulphuric acid were the only acids tried and, since results with acetic acid were obtained which were satisfactory for routine work, no other acids

were investigated. The coefficient of variation found by calibrating the same pipette with benzyl benzoate on a "to deliver" basis was 0.8 per cent. Pipettes may be calibrated "to contain" with mercury to a higher degree of accuracy. "To contain" pipettes, however, are not as satisfactory for routine work. Careful work by one author using a "to contain" and a "to deliver" pipette resulted in a coefficient of variation for eight spreads of 1.7 per cent for the former and 1.6 per cent for the latter. Tracing from the glass to paper results in a small error of less than 1.0 per cent. Planimeter measurements made of the same tracing on paper eight times resulted in a coefficient of variation of 0.6 per cent. The error resulting from weighing the ether on a Torsion balance was estimated to be less than 1 per cent. The change in weight as determined on an analytical balance was about 2 mg. per sec. and only a few seconds elapse from the time the pan is balanced until the 0.0072-ml. aliquot is taken. Extraction errors for the "drop test" were not adequately determined, since a microbalance was not available. Averaging of a large number of results does indicate that extraction usually is complete. Oxidation of the fatty extract in the pan while on the hot plate was found to be of a negligible nature. The effect of seasonal and geographical variations in the composition of the fat was not determined.

Under routine conditions, the "drop test" may be completed in 12 to 13 min. Some experienced operators may estimate the fat surprisingly well by visual measurement of the area of the spread. The difference between a fat test on skimmilk of 0.07 and 0.09 per cent is easily recognized by judging the area. If such an approximate "high or low" value is desired, results may be secured in about 10 min.

Under ideal conditions, the coefficient of variation is around 2.5 per cent, under routine conditions this value is almost twice as great. For practical purposes, the 25-ml. aliquot of a single extraction evaporated to dryness, ether added, the aliquot spread once, the area traced to glass three times and the per cent fat calculated from the average area will yield a result within $\pm$ 0.01 per cent fat of the true value for skimmilk and $\pm$ 0.10 per cent fat for nonfat dry milk solids. These values approximate those obtained by the Mojonnier method. Ten aliquots of the same sample of skimmilk tested by the Mojonnier had a mean of 0.055 per cent, a standard deviation of $\pm$ 0.0048 per cent and the coefficient of variation was 8.7 per cent. On ten aliquots of the same skim tested by the "drop test" the coefficient of variation was 7.5 per cent, the mean was 0.052 per cent and the standard deviation was $\pm$ 0.0039 per cent. These results probably represent the maximum errors obtained in both methods, since the quantity of fat in this sample was low. When a sample of nonfat dry milk solids was tested seven times by different individuals using the Mojonnier test, the mean was 0.96 per cent, the standard deviation was 0.092 per cent and the coefficient of variation was 9.6 per cent. The same sample of nonfat dry milk solids was tested by the "drop test" by different individuals. The mean of these results was 0.96 per cent, the standard deviation was 0.037 per cent and the coefficient of variation was 4.5 per cent.

CONCLUSIONS

1. A method is described for determining fat in skimmilk and nonfat dry milk solids which is suitable for routine use.

2. The method is based on measuring the area of a monolayer of fatty extract formed by transferring 0.007 to 0.008 ml. of its ether solution to a prepared surface on a solution of 0.2 per cent acetic acid.

3. Errors in the method are discussed.

4. Results are reported which indicate close agreement between the proposed method and standard Mojonnier procedures for the two products tested.

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THE NUTRITIVE VALUE OF ALFALFA HAY. IV. BEET PULP, CORN GLUTEN MEAL AND SOYBEAN OIL MEAL AS SUPPLEMENTS TO AN ALL-ALFALFA HAY RATION FOR MILK PRODUCTION[1]

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It generally is recognized that the total digestible nutrients (T.D.N.) that cattle receive from an all-roughage ration are not as efficient for milk production as when the roughage is supplemented with concentrates. Kellner and Köhler (14) attributed the lower milk-producing value of the T.D.N. in roughages to their high crude fiber content. In a previous report (11), it was shown that properly depleted cows failed to increase in milk production when corn starch or glucose was added to an all-alfalfa hay ration, but when an equal amount of corn or wheat replaced the starch, milk production always increased, even though the crude fiber content in the dry-matter of the ration was practically constant. These results signify that both corn and wheat supplied the unidentified factor(s) needed for more efficient milk production. Several investigators (3, 9, 10, 12, 13, 20) have reported that the replacement of part of the T.D.N. in roughage with various concentrates has increased milk production. Smith *et al.* (20) stated that the inadequacy of an all-alfalfa hay ration for milk production was not due to a deficiency of total protein. Huffman and Duncan (10) also showed that the lowered efficiency for milk production of cows depleted on an all-alfalfa hay ration was not due to a deficiency of cystine.

The possibility of a deficiency of dietary fat as being responsible for the inefficiency of milk production of the depleted cows was suggested by the low fat content of alfalfa hay. The work of Maynard *et al.* (16) also indicated that a certain level of fat was needed in the dairy ration for optimum milk production. The present paper reports the results obtained by replacing part of the T.D.N. in an all-hay ration with low-fat beet pulp, sugar beets, corn gluten meal and soybean oil meal.

The purpose of this investigation has been to elucidate the nature of the nutrient precursors which are necessary for efficient milk production but are lacking in an all-hay ration.

EXPERIMENTAL

The method of handling the experimental cows and the depletion technique employed in this work have been described previously (9). Three Jersey cows (66, 77, 127) and five Holstein cows (D9, D14, C167, A6, A18) were used to study the effect of dry beet pulp supplementation. Two Holstein cows (D14, A6) were used to investigate the milk-stimulating power of sugar beets. Two Jersey

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TABLE 1

Description of the hays, their chemical composition and their actual or calculated coefficients of digestibility

Trial no.	Cow no.	Moisture	Ash	Protein[b]	Ether ext.	Crude fiber	N.F.E.	Dig. protein	T.D.N.	Description of the hays
		(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	
1[a]	D9	13.6	6.79	16.4 66	2.04 41	25.7 50	35.5 67	10.8	49.3	U.S. No. 2, No. 1 on leaf, 2nd cut. alf., 1937 crop
2	D14	14.6	5.97	14.5 66	1.33 41	28.2 50	35.4 67	9.6	48.6	Same as trial 1.
3	C167	16.6	5.79	12.4 72[b]	2.19 34	29.8 43	33.2 71	8.9	47.0	U.S. No. 3, 1st cut. alf.-brome, 1938 crop
4	127[c]	12.8	5.04	10.4 72[b]	1.50 31	32.8 43	37.5 70	7.5	48.9	U.S. No. 2, 1st cut. alf.-clover-tim., 1943 crop
6	A6[d, e]	11.7	6.75	16.4 71	1.67 0	29.0 41	34.5 69	11.6	47.3	U.S. No. 3, No. 1 on leaf, 2nd cut. alf., 1940 crop
9	D14[f]	13.8	7.82	16.4 72[b]	1.80 34	28.3 43	31.9 71	11.8	47.2	U.S. No. 1, 2nd cut. alf., 1937 crop
11	A6	10.6	6.67	10.9 67[b]	0.88 18	35.5 45	35.5 64	7.3	46.4	U.S. No. 3, 1st cut. alf.-clover, 1937 crop
12	A15	12.7	6.09	13.1 67	2.12 37	30.5 57	35.5 62	8.8	49.9	Ungraded 2nd cut. alf.-brome, 1941 crop
13	74	11.9	6.37	9.4 67[b]	1.98 18	39.0 45	31.4 64	6.3	44.8	U.S. No. 3, 1st cut. alf.-brome 1937 crop

TABLE 1 (*continued*)

Trial no.	Cow no.	Moisture	Ash	Protein[b]	Ether ext.	Crude fiber	N.F.E.	Dig. protein	T.D.N.	Description of the hays
		(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	
14	76	10.4	5.89	11.3	1.10	36.3	35.0	7.6	46.8	Ungraded 1st cut. alf.-clover-tim., 1942 crop
				67[b]	18	45	64			
15	442[g]	9.4	5.33	9.8	1.46	36.0	38.0	5.0	51.8	U.S. No. 3, 1st cut. alf.-brome, 1946 crop
				51[b]	39	59	64			
16	A29[h]	10.6	5.45	9.9	1.32	35.4	37.3	5.0	51.0	U.S. No. 3, 1st cut. alf.-brome, 1946 crop
				51[b]	39	59	64			
18	D14	11.7	6.75	16.4	1.67	29.0	34.5	11.8	50.1	U.S. No. 1, 2nd cut. alf., 1939 crop
				72[b]	34	43	71			
19	A6	14.6	5.97	14.5	1.33	28.2	35.4	10.4	48.7	U.S. No. 1, 2nd cut. alf., 1937 crop
				72[b]	34	43	71			
20	78	11.6	7.19	13.3	2.30	30.4	35.2	9.6	49.4	U.S. No. 1, 1st cut. alf.-brome, 1943 crop
				72[b]	34	43	71			

[a] The first line in each trial represents the chemical composition of the hay.

[b] The second line in each trial represents the coefficients of digestibility of the various hay fractions. Those marked with footnote [b] represent the calculated values, whereas all other values were obtained experimentally.

[c] Cow 66 (trial 5) received this hay.

[d] Cow 77 (trial 7) received this hay.

[e] Cow A18 (trial 8) received the same hay as cow D14 (trial 2).

[f] Cow A6 (trial 10) received this hay.

[g] Cow 423 (trial 21) received this hay.

[h] Cow A46 (trial 17) received this hay.

cows (74, 76) and six Holstein cows (A6, A15, A29, A46, D14, 442) were used to study the effects of corn gluten meal. One Jersey cow (78) and two Holstein cows (A6, 423) were used on the soybean oil meal experiment. Twenty-one individual trials are reported, but cows D14 and A6 were used on three and four different trials, respectively, with different hays (table 3). The cows varied from 43 to 466 days in lactation and from 0 to 172 days in gestation at the start of the experimental period. Non-pregnant cows were used in eight trials.

The milk was weighed at each milking and 3-day composite samples were taken for butterfat determinations. The equivalent number of pounds of 4 per cent fat-corrected milk (F.C.M.) were calculated by the formula proposed by Gaines (6). The cows were weighed at the same hour every third day. The average figures for each of the above measurements are recorded in table 3.

The length of time varied from 6 to 8 days prior to the addition of a supplement, depending on the length of time necessary to deplete the cow of the grain factor(s). The length of time the hay-supplement ration was fed varied from 9 to 36 days.

The 14 hays used in this study represent 8 crop years. Both first and second cuttings of hay harvested from early bloom to full bloom were used. In all cases the hays were fed within 1 yr. after harvest. The description of the hays, their chemical composition, coefficients of digestion, digestible crude protein and T.D.N. content are presented in table 1. The actual coefficients of digestion were used whenever they were available, otherwise the coefficients recommended by Morri-

TABLE 2

The chemical composition, digestible protein and total digestible nutrient content of the supplements used in each trial

Trial no.	Cow no.	Moisture	Ash	Protein	Ether ext.	Crude fiber	N.F.E.	Dig. protein	T.D.N.
		(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
				Beet pulp					
1	D9[a]	11.6	2.78	8.94	0.10	19.8	56.8	4.2	67.3
3	C167	11.4	2.88	8.94	0.37	20.6	55.8	4.2	67.1
4	127[b]	12.4	2.74	9.00	0.25	19.1	56.2	4.2	66.5
6	A6	13.5	3.89	9.56	0.79	19.3	53.0	4.5	64.0
				Corn gluten meal					
11	A6	11.1	0.97	43.69	1.99	2.7	39.6	37.1	79.6
12	A15	10.0	1.73	42.06	1.58	2.3	42.3	35.8	79.8
13	74	9.2	1.51	45.31	2.39	3.7	37.9	38.5	80.9
14	76	9.5	1.51	47.06	2.12	1.4	38.4	40.0	81.0
15	442[c]	10.0	3.00	43.47	3.02	3.0	37.5	36.9	79.6
18	D14	9.5	1.28	42.38	4.28	4.3	38.3	36.0	83.0
				Soybean oil meal					
19	A6	10.8	5.87	45.63	0.71	5.4	31.6	42.0	77.5
20	78	9.5	5.67	46.75	2.37	5.3	30.4	43.0	78.7
21	423[d]	10.7	5.55	44.70	4.04	6.1	28.9	41.1	77.9

[a] This beet pulp was used for trials 2, 7, 8 (Cows D14, 77, A18).
[b] This beet pulp was used for trial 5 (Cow 66).
[c] This corn gluten meal was used for trials 16 and 17 (Cows A29 and A46).
[d] This soybean oil meal was used in trial 15 (Cow 442), see table 3.

son (17) were used. The chemical composition, digestible protein and T.D.N. values for beet pulp, corn gluten meal and soybean oil meal, calculated from the more liberal recommendations suggested by Morrison (17), are presented in table 2. No chemical analyses were made on the sugar beets, but Morrison's digestible protein and T.D.N. values were used in the calculations in table 3.

RESULTS

The data showing stage of lactation, body weight, butterfat test, average daily yield of 4 per cent F.C.M., hay and supplement intake, T.D.N. received and required and per cent of crude fiber ingested by each cow, calculated on the dry-matter basis, are presented in table 3. When dry beet pulp replaced part of the hay, on an equal T.D.N. basis, there was a marked reduction in crude protein intake, but when corn gluten meal or soybean oil meal replaced part of the T.D.N. in the hay, the crude protein intake increased markedly.

In trials 1, 3 and 6, the T.D.N. received per day during the hay periods and hay-beet pulp periods were essentially the same, while in trials 2 and 7, cows D14 and 77 received 2.6 and 2.4 lb., respectively, less T.D.N. per day than when fed hay alone. In trials 4, 5 and 8, the cows received about 1 lb. less T.D.N. during the hay-beet pulp periods than from the all-hay rations. The T.D.N. intake for the two cows receiving the sugar beet supplement was approximately equal, but there was a significant increase in milk production. In all but one of the eight trials with corn gluten meal, the nutrient intakes were about the same as during the hay periods. In trial 18, the T.D.N. intake was only 0.4 lb. more when 6 lb. of corn gluten meal replaced 6 lb. of corn starch. The lowest percentage increase in milk production was obtained from D14 (trial 18) which received over 4 lb. more T.D.N. during both supplemented periods than during the all-hay period. Less T.D.N. were fed in the three hay-soybean oil meal rations than in the hay rations.

A significant increase in F.C.M. was obtained in seven of the eight trials when part of the T.D.N. of hay was replaced by beet pulp. Cow A18 (trial 6) increased only 0.2 lb. per day in milk production but she had been milking for 465 days prior to the start of the experiment. It is likely that she was affected by some deficiency other than the grain factor(s), since a large excess of T.D.N. was received from both rations. The average increase in F.C.M. per cow per day obtained from the low-fat beet pulp supplement was 17.2 per cent (range, 1.2–34.2). Sugar beets stimulated decided increases in milk production in D14 and A6 (trials 9 and 10). Corn gluten meal produced a significant increase in milk production in all trials. In trial 11, 3 lb. of cottonseed meal replaced 3 lb. of corn gluten meal for a 12-day period and a drop in milk production resulted, but when the hay intake was reduced 8.8 lb. and 9 lb. of corn gluten meal replaced the 3 lb. of cottonseed meal, an increase of 7.9 lb. of milk per day was obtained for the next 15-day period. The T.D.N. intake was only 0.6 lb. more than was received from the all-hay ration. The feeding of 6 lb. of corn starch per day as a supplement to the all-hay ration (trial 18) depressed milk production, but when 6 lb. of corn gluten meal replaced the 6 lb. of starch, a marked increase in milk pro-

TABLE 3

The effect of various supplements to an all-hay ration on the average daily yield of 4 per cent fat-corrected milk and on the crude fiber content of each ration, calculated on the dry-matter basis

Trial no.	Cow no.	Exptl. period	In milk	Body wt.	Fat test	F.C.M.		Feed intake		T.D.N.		Crude fiber in D. M.
						Yield	Incr.	Hay	Suppl.	Rec.	Req.	
		(*d.*)	(*d.*)	(*lb.*)	(%)	(*lb.*)	(%)	(*lb.*)	(*lb.*)	(*lb.*)	(*lb.*)	(%)
						Beet pulp						
1[a]	D9	15	99	1192	3.43	28.4	.....	38.5	.....	19.0	18.9	29.7
		18	114	1162	3.42	33.8	19.0	23.6	10.5	18.7	19.2	27.5
2	D14	6	167	1240	3.20	19.8	.....	44.3	.....	21.5	15.5	33.0
		36	173	1209	3.21	23.2	17.2	24.3	10.5	18.9	16.7	29.7
3	C167	12	84	1264	3.03	18.5	.....	33.8	.....	15.9	15.5	35.7
		9	96	1250	2.90	22.3	20.5	24.0	7.0	16.0	16.7	32.8
4	127	15	224	740	5.66	6.6	.....	20.0	.....	9.8	8.0	37.6
		18	239	738	6.27	7.4	12.1	10.0	6.0	8.9	8.3	31.7
5	66	15	137	740	4.79	7.6	.....	24.0	.....	11.7	8.4	37.6
		15	152	738	5.36	10.2	34.2	14.0	6.0	10.8	9.2	32.9
6	A6	15	466	1237	2.87	16.7	.....	38.6	.....	18.3	14.7	32.8
		12	481	1228	3.23	16.9	1.2	24.9	10.0	18.2	14.8	29.9
7	77	15	335	841	6.04	12.4	.....	29.1	.....	13.8	11.0	32.8
		30	350	829	6.65	13.6	9.7	9.8	10.0	11.4	11.3	27.6
8	A18	15	283	1036	3.63	14.1	.....	34.4	.....	16.7	12.7	32.0
		15	298	1038	3.53	17.4	23.4	14.8	12.2	15.7	13.8	25.8
						Sugar beets						
9	D14	15	59	1238	3.14	28.3	.....	45.0	.....	21.5	18.4	
		15	74	1202	3.29	31.7	12.0	30.0	55.0	21.9	19.5	
10	A6	15	113	1037	2.69	24.8	.....	42.0	.....	20.1	16.2	
		12	128	1033	3.27	29.7	19.8	25.0	55.0	19.5	17.7	
						Corn gluten meal						
11	A6	12	158	1066	3.00	21.1	.....	43.4	.....	20.1	15.1	39.7
		12	170	1084	2.90	26.1	23.7	38.0	3.0	20.0	16.9	37.3
		12	182	1109	3.00	23.3	.....	38.0	3.0[e]	19.9	16.1	37.8
		15	197	1089	3.10	29.0	37.4[d]	29.2	9.0	20.7	18.0	37.2
12	A15	15	261	1183	4.28	13.1	.....	35.0	.....	17.5	13.3	35.0
		21	276	1143	3.88	16.0	22.1	25.0	6.0	17.3	13.9	28.5
13	74	18	279	769	5.18	15.5	.....	32.8	.....	14.7	11.5	44.3
		24	297	758	5.37	19.0	22.6	14.0	6.0	11.1	11.7	32.0
14	76	15	248	869	4.35	8.9	.....	24.8	.....	11.6	10.0	40.5
		21	263	862	5.04	12.8	43.8	15.0	6.0	11.9	11.3	29.3
15	442	15	150	1119	3.60	20.7	.....	50.0	.....	25.9	15.3	39.7
		18	165	1117	3.40	24.7	19.3	43.0	3.5	25.1	16.6	37.0
		15	183	1105	3.30	24.8	19.8[d]	43.0	3.5[e]	25.1	16.5	37.3
16	A29	12	281	1181	3.40	9.8	.....	32.8	.....	16.7	12.2	39.6
		12	293	1175	3.40	12.5	27.6	26.8	3.0	16.1	13.1	35.9
17	A46	12	274	1136	3.90	9.1	.....	35.8	.....	18.3	11.7	39.6
		12	286	1145	4.00	10.5	15.4	30.0	3.0	17.7	12.3	36.3
18	D14	15	146	1233	3.36	26.0	.....	44.3	.....	22.2	17.7	32.8
		15	161	1212	3.14	24.4	.....	42.1	6.0[f]	26.2	17.1	29.2
		12	176	1229	3.23	26.4	8.2[g]	43.1	6.0	26.6	18.8	29.3
						Soybean oil meal						
19	A6	15	224	1136	2.80	21.9	.....	44.1	.....	21.5	15.7	33.0
		21	239	1152	2.91	23.5	7.3	28.1	9.0	20.7	16.4	24.7
20	78	12	296	992	5.25	6.1	.....	34.8	.....	17.2	10.0	34.4
		30	308	966	5.00	9.2	50.8	20.0	6.0	14.6	10.1	27.7
21	423	15	43	1105	3.00	25.5	.....	35.6	.....	18.4	16.8	39.8
		18	58	1083	3.10	29.3	14.9	29.9	3.5	18.2	17.5	36.3

[a] The first line in each trial represents the all-alfalfa hay ration, whereas the second or more lines represent the hay-supplement ration.

[b] Supplement contained 9 lb. of beet pulp plus 3 lb. of corn sugar daily. [c] Cottonseed meal. [d] Percentage increase over the all-hay ration. [e] Soybean oil meal. [f] Corn starch. [g] Percentage increase over the alfalfa-starch ration.

duction was obtained. The average increase in milk production was 24.0 per cent per cow per day (range, 8.2–43.8) when corn gluten meal supplemented the all-hay ration. Soybean oil meal also produced a significant increase in milk production on a lower T.D.N. intake. The average increase was 24.3 per cent for the three trials.

The per cent of butterfat increased in four trials, but was unchanged or slightly decreased in the other four trials when beet pulp supplemented the all-hay ration. The two cows fed the sugar beets showed an increase in per cent of fat but no significant differences were obtained when corn gluten meal or soybean oil meal were fed, except in trial 14. The corn gluten meal fed in trials 11 to 14, inclusive, and the soybean oil meal fed in trials 19 and 20 contained from 0.71 to 2.39 per cent ether extractive materials. The ether extract of the hays used in all of the trials varied from 0.88 to 2.30 per cent, but the increases obtained in milk production do not appear to follow the ether extract.

The last column in table 3 gives the percentage of crude fiber in each ration, calculated on the dry-matter basis. The lowest percentage increase in milk production (trial 19), other than trial 6, was associated with a 25.2 per cent reduction in crude fiber intake, whereas the lowest crude fiber reductions (trials 11 and 15) gave percentage increases in milk production of 23.7 and 19.8 per cent, respectively. The highest percentage increase in milk production was obtained in trial 20, when the crude fiber intake was 19.5 per cent less than that in the all-hay ration. It would appear from these data that a reduction in crude fiber intake is not necessarily correlated with a corresponding increase in milk production.

DISCUSSION

The replacement of part of the T.D.N. in the rations of properly depleted cows with dry sugar beet pulp resulted in an increase in the production of 4 per cent F.C.M. The largest increase in milk production was made by cow 66 (trial 5) when 6 lb. of beet pulp replaced 10 lb. of first-cutting alfalfa-clover-timothy hay. The smallest increase was made by cow A6 (trial 6) which had already completed 465 days of lactation at the beginning of the experiment. There is a possibility that some deficiency other than the grain factor(s) was responsible for this small increase, in view of the fact that an excess of 3.4 lb. of T.D.N. was consumed per day over that required. The increases obtained in F.C.M. are in agreement with the results secured by Smith *et al.* (20), who reported an increase in milk production in two cows when part of the T.D.N. in an all-alfalfa hay ration was replaced with beet pulp.

When 55 lb. of sugar beets replaced hay on an equal T.D.N. basis, two cows, D14 and A6 (trials 9 and 10), increased 12.0 and 19.8 per cent, respectively, in F.C.M. It would appear from the results obtained from supplementing the all-hay rations with low-fat beet pulp or sugar beets that the first deficiency of an all-hay ration is the grain factor(s) and not fat, as might be anticipated on the basis of the low fat content of alfalfa hay and the above supplements. Cow D14 (trial 2) was fed beet pulp for 36 days without being depleted of fat; however,

she had been depleted of the grain factor(s) for only 6 days prior to the replacement of hay with beet pulp. Maynard *et al.* (16) have reported that an optimum level of 4 per cent of fat in the grain mixture is necessary for efficient milk production.

Of the ten trials with beet pulp and sugar beets, the per cent of butterfat in the milk was significantly higher in five trials, approximately the same in three trials and only slightly lower in two trials. According to Byers *et al.* (2), a ration of alfalfa hay and ground soybeans containing 5.2 per cent dietary fat did not increase milk production when compared to a ration of alfalfa hay and soybean oil meal containing 2.7 per cent fat, but a significant increase was obtained in the per cent of butterfat when the high fat ration was fed. Gibson and Huffman (7) fed a ration composed of alfalfa hay, beet pulp, beet molasses and solvent-extracted soybean oil meal and obtained a pronounced increase in the per cent of fat in the milk when soybean oil replaced beet pulp on an equal T.D.N. basis, but the increase was of short duration and soon returned to normal. The cows became depleted in fat within 12 days on the low-fat basal ration, but the per cent of fat in the milk increased as the cows became depleted in fat or some factor associated with fat.

The results obtained with beet pulp and sugar beets indicate that the grain factor(s) present in grains and reported previously by Huffman and Duncan (11, 12, 13) and Smith *et al.* (20) is present also in root crops. Davis and Kemmerer (3) reported that milk production was increased when dry grapefruit peel was added to an all-alfalfa hay ration.

In view of the potency of low-protein grains, *i.e.*, wheat and corn, to supply the milk-stimulating factor(s) (11, 13), two high-protein concentrates, corn gluten meal and soybean oil meal, were used to replace part of the T.D.N. in the all-hay rations. Corn gluten meal was used in eight trials and soybean oil meal was used in three trials. Cow A6 (trial 6) was fed two levels of corn gluten meal. At the 3-lb. level, the F.C.M. increased 5 lb. per day, whereas at the 9-lb. level, the increase above the all-hay ration was 7.9 lb. These two feeding periods were separated by a 12-day period during which time 3 lb. of cottonseed meal were fed and a decline in milk production was observed. A direct comparison of corn gluten meal was made with soybean oil meal at the 3.5-lb. level (trial 15) and no significant difference in milk production was obtained from the use of these two supplements. This cow had a very good appetite for hay which accounts for the consumption of a large excess of T.D.N. over that required.

The increases obtained in milk production when low-fat corn gluten meal or soybean oil meal replaced part of the T.D.N. in the all-hay ration indicate further that fat *per se* is not the first deficiency encountered in feeding an all-hay ration.

The results secured from D14 (trial 18) show that the addition of 6 lb. of corn starch to an all-hay ration and the subsequent replacement of the starch with 6 lb. of corn gluten meal resulted in an increase of 2 lb. of F.C.M. above the hay-starch ration. The crude fiber was practically the same in both the hay-starch and hay-corn gluten meal rations. It has been shown previously (11) that milk production

increased when either corn or wheat replaced corn starch or corn sugar, on an equal T.D.N. basis, when properly depleted cows were used, but that the addition of starch or sugar also increased milk production when undepleted cows were used.

The possibility that the observed increase in milk production when grains, beet pulp or sugar beets replace part of the T.D.N. in the hay is due to increased digestibility appears to be unlikely in view of the results obtained by Watson *et al.* (21). They reported that the digestibility of barley by sheep and steers was the same whether fed in combination with timothy or alfalfa hay or alone. Burroughs *et al.* (1) showed that the digestibility of the dry matter in corn cobs was depressed by the addition of starch, but when the same amount of starch was added to alfalfa hay, a depression in digestibility of dry matter did not occur. They explained their results on the basis that alfalfa hay contained more of the essential nutrients for promoting the growth of rumen microorganisms than did corn cobs. The presence of unidentified factors in alfalfa, essential for efficient roughage digestion, has been postulated. Quin (18) found that the rate of fermentation of glucose in the rumen of sheep was slow when fed in combination with poor hay but when alfalfa hay replaced the poor hay the rate of fermentation of glucose increased markedly. The change in the rate of fermentation was correlated with the change in rumen flora. Similar results were reported by Elsden (4). Louw *et al.* (15) showed that the addition of fresh alfalfa to a ration of poor hay supplemented with starch, casein, yeast and a mineral mixture overcame the depression of cellulose digestion. It is probable that when alfalfa hay is included in the ration, no decrease occurs in digestibility that can be attributed to disturbance of the normal rumen flora.

In six of the 21 trials, losses in body weight were greater than 15 lb., in two trials the gain in weight was more than 15 lb., but the cows in all of the rest of the trials showed weight losses or gains of less than 15 lb.

The depletion and partial T.D.N. replacement technique used in these studies resulted in a reduction in dry matter intake when concentrates replaced part of the hay. The effect of changing the dry matter intake on fill has been investigated by Ritzman and Benedict (19). The actual loss of fill in lactating dairy cows, fasted 4 days, was found to be about 15 per cent of the live weight, but the cows were fed 14 kg. of hay per day during the "so-called" fast. Hale *et al.* (8) reported that when a cow was changed from 30 lb. of alfalfa hay per day to 15 lb., there was a loss of 4.7 lb. in live weight per pound decrease in dry matter intake. When a cow was changed from 5 to 20 lb. and from 20 to 30 lb. of alfalfa hay daily, the weight increases per pound of dry matter intake were 5.6 and 9.9 lb., respectively. On this basis, a loss of 4.7 lb. of live weight per pound of reduced dry matter intake would account for the decline in body weight of all of the cows used in this study. Forbes *et al.* (5) studied the metabolism of a steer fed alfalfa hay alone, corn alone and alfalfa hay and corn and found that live weight declined in proportion to the decrease in dry matter consumption. The loss was greater when the corn ration was fed and intermediate when hay and corn were

fed. The net energy was much greater per pound of dry matter, however, when both hay and corn were fed than when either was fed alone.

SUMMARY

Sixteen cows which had been depleted of the grain factor(s) were used in 21 trials to study the effect on milk production by replacing part of the T.D.N. in an all-hay ration with either beet pulp, sugar beets, corn gluten meal or soybean oil meal.

In 9 of 10 trials a significant increase in 4 per cent F.C.M. was obtained when various levels of beet pulp or sugar beets replaced an equal amount of T.D.N. in the hay.

In 9 of 11 trials a significant increase in F.C.M. was obtained when various amounts of corn gluten meal or soybean oil meal replaced an equal amount of T.D.N. in the hay.

The tendency for the per cent of butterfat in the milk to increase when beet pulp or sugar beets replaced part of the hay was observed.

In view of the low fat content of beet pulp, sugar beets and most of the corn gluten meals and soybean oil meals used in these trials, it is apparent that the first deficiency of an all-hay ration for milk production is not fat *per se*.

The results indicate that the "so-called" grain factor(s) or the unidentified milk-stimulating factor(s) is stored also in beet pulp, sugar beets, corn gluten meal and soybean oil meal.

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PREDICTABILITY OF BREEDING EFFICIENCY IN DAIRY CATTLE[1]

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The rapid growth of the artificial insemination program and its general adoption by dairy farmers has greatly stimulated the interest in breeding efficiency. Some dairymen have herds requiring many repeat services. It is not unusual for such men to become discouraged and withdraw from the program for a year or more. Dairymen have been advised to cull their herds from the standpoint of breeding efficiency as well as type and milk production. In order to gain more specific information concerning sound advice to furnish dairymen who are posed with herd breeding problems or problems of culling, the present study was made.

Trimberger and Davis (6) reported on the predictability of breeding efficiency in the University of Nebraska dairy herd over an 8-yr. period of time. The number of services required by 133 virgin heifers had no value in predicting the number required for subsequent conceptions. In like manner, the number of services required for the previous pregnancy of 199 cows had no value in predicting the number of services required for the following pregnancy. They also stated that the same principle applies to herds. Included in their study was a comparison of the breeding efficiency of 92 dams with that of their daughters, from which they concluded it was not possible to predict the breeding efficiency of heifers from that of their dams.

In contrast to the results of the Nebraska study, Lasley and Bogart (3) reported the repeatability of breeding performance for 120 range cows. They found that 80 cows having a good breeding record the first year continued to have a good record the next 2 yr. The 40 cows which had a poor record the first year continued to have a poor record the next 2 yr.

Jones *et al.* (2), in reporting a study of the Oregon State College dairy herd covering a period of 25 yr. and including 368 cows of four breeds, concluded that the inheritance of low fertility and close-breeding practices might account for much of the infertility found in dairy herds today. Spielman and Jones (5) in a study of the same herd, found a correlation of 0.546 ± 0.118 between the mean reproductive efficiency of foundation cows and that of their daughters.

Olds *et al.* (4) found no significant correlation between the breeding efficiency of 91 dams and that of their daughters in the Kentucky Agricultural Experiment Station herd.

EXPERIMENTAL PROCEDURE

Herd record books for twenty local cooperatives of the Kentucky Artificial Breeding Association were obtained covering 2 yr. of operation (1947–48 and

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1948–49). Breeding efficiency data from these books were tabulated for 6,509 cows and 2,403 herds which were serviced both of the consecutive years. Breeding efficiency was based on "non-returns" with all cows having at least 4 mo. in which to return for another service. According to work by Barrett *et al.* (1), these non-returns should be a reasonable approximation of actual conception. For this reason, the term "conception" has been used frequently for simplicity instead of "non-returns."

RESULTS

There were 20,263 cows bred in the twenty locals during the first year of this study (1947–48), and of those only 6,509 or 32.1 per cent appeared in the records during the second year (1948–49).

It was found that 4,665 cows, each of which required only one service the first year, averaged 1.44 services the second; 1,372 cows requiring two services the first year averaged 1.54 services the second; 400 cows requiring three services the first year averaged 1.64 services the second. The 72 cows which required four services the first year averaged 1.65 services the second. As the number of

TABLE 1

Per cent of cows which required 1, 2, 3 or 4 services the second year within groups conceiving at 1st, 2nd, 3rd or 4th service the first year

	Service at which probable conception occurred 1st yr.			
No. of cows	1st	2nd	3rd	4th
	4665	1372	400	72
	% of cows			
Services required 2nd yr.				
1	68.5	63.0	57.3	62.5
2	21.0	23.3	24.8	16.7
3	8.4	10.3	14.0	13.9
4	2.1	3.4	4.0	6.9

services required the first year increased, there was a rather uniform increase in the average services required the second year. However, the differences were not great, averaging 0.1 service between the first two groups and less than that between the third and fourth service groups (0.01 service). The number of cows for the fourth group (72) was markedly smaller than for the other groups.

The number of cows conceiving at first, second, third or fourth service the first year and the percentage of each group which required one, two, three or four services the following year are given in table 1. As the number of services required the first year increased, the per cent of cows conceiving at first service the following year showed a downward trend, except in the last or fourth service group. The irregular trend for this group may be due to the smaller number of cows (72) involved. As the number of services required the first year increased, the per cent of cows conceiving at second and third service the following year showed a highly significant upward trend. Again, the small fourth service group did not follow this trend.

The correlation between the number of services required by cows the first year as compared to the number of services for the second year was 0.084 ± 0.012 ($p < .01$). This correlation, although statistically highly significant, was too small to indicate a high degree of predictability. The coefficient of determination (r^2) shows that only 0.71 per cent of the variation between cows the second year could be accounted for by their performance the first year.

The percentage of cows which required the same number of services both years was 54.9. As would be expected, those requiring but one service the first year scored highest in this regard, with 68.4 per cent of them also having but one service the second year. In contrast, only 23.3 per cent in the two-service group, 14.0 per cent in the three-service group, and 6.9 per cent in the four-service group had identical records for the second year.

Predictability of breeding efficiency for herds. There were 2,403 herds in which cows were bred during both of the 2 yr. The average herd consisted of 7.1 cows the first year and 8.3 cows the second. The breeding efficiency was based upon average number of services per cow, using the herd as a unit.

Table 2 shows the number of herds within each of four efficiency groups and

TABLE 2

Repeatability of breeding efficiency of herds

	Av. no. of services required the 1st yr.			
No. of herds	1.0–1.5	1.6–2.0	2.1–2.5	2.6–3.0
	1526	705	121	51
Services required 2nd yr.	% of herds			
1.0–1.5	69.0	59.6	50.4	70.6
1.6–2.0	25.6	34.3	36.4	29.4
2.1–2.5	3.5	3.8	8.3	0.0
2.6–3.0	1.9	2.2	5.0	0.0

the per cent of these herds which were in each of these groups the second year.

The percentages for the various groups and the trends shown in table 2 are somewhat similar to those of table 1. It will be of some encouragement to dairymen with problem herds to notice that of the 172 herds which averaged more than two services per cow the first year, only 16 herds (9.3 per cent) were still that low the next year. Also, it is of interest that 54.3 per cent of the herds had about the same breeding efficiency both years. This figure was determined largely from data of herds averaging less than two services per cow. The portion of the total herds that were "problem herds" (having 2.1 or more services per cow) remained about the same both years, *i.e.*, 7.1 per cent the first year and 5.9 per cent the second.

SUMMARY

The breeding efficiency of 6,509 cows and for 2,403 herds was compared for 2 consecutive yr. As the number of services required by cows the first year in-

creased, there was a rather uniform increase in the average number of services required the second year. However, the differences were not great, increasing approximately 0.1 service for each service increase of 1.0 for the first year. Nearly 55 per cent of the cows required the same number of services both years. The correlation between breeding efficiency for consecutive years was 0.084 ± 0.012.

The predictability of breeding efficiency of herds was about the same as that for cows. About 54 per cent of the herds required approximately the same average number of services per cow both years. Only 9.3 per cent of the "problem herds" (averaging 2.1 or more services per cow) were still problem herds the next year. The total number of problem herds remained about the same both years, *i.e.*, 7.1 per cent the first year and 5.9 per cent the second.

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STUDIES ON GROWTH AND SURVIVAL OF CALVES FED SEMI-SYNTHETIC MILKS FROM BIRTH[1]

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The use of purified diets to study the nutritional needs of young calves is a relatively recent development. Johnson *et al.* (11) reported subnormal growth of colostrum-fed calves raised on a purified mixture of casein, lactalbumin, sugar, lard or butter and water. Supplementation with riboflavin, thiamine, yeast or grass juice did not give consistent improvement in growth. Wiese *et al.* (17) reported the development of a synthetic milk which promoted good growth in young calves. They observed that growth rates of calves receiving the synthetic milk with lard were normal according to the Ragsdale standard (15), but that calves fed this milk with soybean oil grew poorly. In an experiment reported by Flipse *et al.* (6) on three 5-day-old calves, corn sugar was found to be superior to dextrin or corn starch when these carbohydrates were incorporated into milk substitutes. Investigations by Gullickson *et al.* (7), Bate *et al.* (2) and Jacobson *et al.* (10) have shown that dairy calves do not grow well and are subject to digestive disturbances on diets containing oils from plant sources fed with skimmilk.

While it generally is believed that colostrum is indispensable to the newborn calf, studies by Lundquist and Phillips (13) and Hansen *et al.* (8) have demonstrated that Holstein calves could be raised on a diet composed solely of skimmilk and added vitamins.

These successes prompted a study to determine whether the young calf could be raised on a synthetic diet without either milk or colostrum. For this purpose a semi-synthetic milk was developed to replace the normal colostrum and whole milk diet. The effect of variations in the composition of this milk on the survival and growth performance of young calves was studied.

EXPERIMENTAL PROCEDURE

The calves used in the experiments were obtained from local farms and from the station dairy herd. These calves were denied colostrum by prearrangement with the owners of the dams. Since the animals were not protected by colostrum feeding, experiments were conducted in the laboratory animal room except when otherwise noted. Weights of the animals were obtained when received and at approximately weekly intervals while on the experimental rations. Protocols were kept on each calf. Blood samples for serum nitrogen and for electrophoretic studies were taken from a few of the animals before they were given food and at various intervals thereafter. Post-mortem examinations were made.

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Antibiotics were used as indicated since experience had shown that colostrum-free calves often succumb to infections which are harmless to older animals.

Two semi-synthetic milks were used. Milk 1 (Ca: Na of 0.7: 0.9) (table 1)

TABLE 1

Composition of synthetic milks 1 and 2 (g. per kg. final liquid milk)

Components milk 1		Components milk 2	
Crude casein	35.0	Crude casein	35.0
Cerelose	50.0	Cerelose	50.0
Cottonseed oil	10.0	Butterfat[c]	.....
Egg albumin	8.0	Salts[d]	.....
Salts IV[a]	4.0	Citrus pectin	2.0
Soya lecithin[b]	2.0	Soya lecithin	2.0

[a] Salt mixture of Phillips, P. H., and Hart, E. B. J. Biol. Chem., 109: 657. 1935.
[b] Generously supplied by Associated Concentrates, Inc., 32nd Ave., Woodside Long Island, N. Y.
[c] When fed, the level was 2.5 or 3.5%.
[d] See table two.

was prepared as described by Wiese *et al.* (17) with some modifications. A water emulsion of soya lecithin and cotton seed oil prepared in a Waring blendor was added after the casein, egg albumin, sugar and salts were brought into solution. Water was added to give a solids content of 109 g. per liter. The emulsification of the oil was considered advisable since it had been shown by Gullickson *et al.* (7) that a diet of lard homogenized into skimmilk was satisfactory for calves. The fact that vegetable oils were not tolerated despite homogenization presented the possibility that they contained insufficient phospholipid. The artificial milk was fed at a temperature of 37° C. from nipple-fitted pails. Calves were fed twice a day, half the daily allowance at each feeding. All the known vitamins except B_{12} were fed in generous amounts, as indicated in table 2.

TABLE 2

Vitamin supplement

Vitamin	Quantity
Ascorbic acid	150 mg. capsule/d.
Vitamin A	250,000 I.U. capsule first 3 d.
" A	5,000 I.U. " daily from 4th d.
" D	500 I.U. " " " " " "
Thiamine	5.0 mg. }
Riboflavin	5.0 " }
Pyridoxine	5.0 " }
Ca Pantothenate	7.5 " }
Niacin	15.0 " }
Inositol	100.0 " } fed daily by capsule
Menadione	1.25 mg. }
Biotin	0.05 " }
Pteroylglutamic acid	0.25 " }
p-Aminobenzoic acid	12.50 " }
Choline	1.0 g. mixed into milk daily
α-D-tocopherol	40.0 mg. " " " "
B_{12}[a]	7–10 γ/d.

[a] Estimated from analysis of crude casein.

RESULTS

Three calves were fed (per 100 lb. of live weight) daily levels of 3 to 7 kg. of synthetic milk 1. The data in table 3 show the results of this experiment, which

TABLE 3

Summary data on new-born calves fed synthetic milk 1

Calf	1	2	3
Breed	Ayrshire	Brown Swiss	Holstein
Birth weight	85 lb.	93 lb.	93 lb.
Time diarrhea developed	24 hr.	24 hr.	24 hr.
Preventive measures	fat removed 5th d.	no fat fed	no fat fed
Duration of diarrhea	10 d.	3 d.	2 d.
Apparent cause of death	?	pneumonia	pneumonia

was conducted in an isolated area of the Station dairy barn. In this experiment all attempts to control diarrhea were unsuccessful. Reduced feedings, administration of Kaopectate and the removal of the fat from the ration were without beneficial effect. It was impossible to determine the causes of the diarrhea. Antibiotics were not used. Post-mortem examination revealed a general gastro-enteritis. There was no evidence of coagulated casein in the stomachs, and the ingesta of the intestinal tract was liquid, resembling the synthetic milk in appearance. Pneumonia was the terminal cause of death of the two animals. Since there was no indication of digestion in the gastro-intestinal tract, evidence was sought that would throw light on this problem.

It has been shown repeatedly that rennet coagulation of milk is inhibited in the absence of sufficient amounts of calcium and retarded by improper ionic balance. Other methods of preparing a synthetic milk then were investigated. A casein solution containing salts in concentrations which occur in normal milk was prepared according to the method of Clark (4). Lime water was used in place of the $NaHCO_3$ solution to dissolve the casein. The remaining elements were added according to his method with the exception that 0.1 *N* HCl was used to adjust the final pH of the milk to 6.6. To this casein solution were added cerelose, soya lecithin and trace minerals to give milk 2 (Ca : Na of 2.5 : 1.0) with the final composition shown in tables 1 and 4. When fat was added, it was

TABLE 4

Salt composition of synthetic milk 2[a]

Component	Quantity/kg. milk	Component	Quantity/kg. milk
$Ca(OH)_2$	1.200 g.	KOH	0.959 g.
MgO	0.298 "	NaOH	0.928 "
KH_2PO_4	2.873 "	Fe citrate	2.0 mg.
Citric acid	1.998 "	$MnSO_4 \cdot H_2O$	0.1 "
$CaCO_3$	0.140 "	$CuSO_4 \cdot 5H_2O$	0 5 "
HCl (0.1N)		$ZnSO_4 \cdot 7H_2O$	10.0 "
$CaCl_2$	1.565 g.	$CoSO_4 \cdot 5H_2O$	1.5 "
		KI	0.4 "

[a] M. W. Clark. Synthetic milk as a basis of research. J. Dairy Sci., 10: 195. 1927.

emulsified with an aqueous suspension of soya lecithin before addition to the milk. Some difficulties were encountered in the initial attempts to make a stable casein solution. Some of the dissolved casein often would precipitate out as small curdy masses when the solution of MgO, citric acid and KH_2PO_4 was added. Efforts to correct this difficulty were made by adding pectin to the casein solution before adding the phosphate solution. The pectin greatly improved the stability of the casein solution in the milk. However, in later work and after more experience had been gained in the preparation of the milk, it was found that precipitation of the casein could be avoided if the phosphate solution was slowly sprayed into the rapidly mixing casein solution. A few calves fed the synthetic milk containing the pectin also received milk without it but no difference in response was noted, hence its use was discontinued.

A considerable number of tests on the behavior of this milk towards rennet coagulation were made. In almost every instance the milk was coagulated in from 3 to 5 min. after the addition of rennet. Comparative tests showed no coagulation of artificial milk 1 (the low Ca milk) during holding periods as long as 3 hr. The data obtained with six calves which were fed synthetic milk 2 are summarized in figure 1.

Calf 4 was kept in the dairy barn, while the other animals were kept in the laboratory animal room. The first experiments were made with milk 2 without fat. Calves 4 and 5 died within 4 and 6 days, respectively, from *Escherichia coli* infections. There was no evidence of diarrhea in these calves and post-mortem examination revealed large clots of casein in their stomachs, a condition not observed in the animals which failed on milk 1. After discovery that the *E. coli* infection had caused the deaths of the animals, the antibiotic dihydrostreptomycin was used to prevent further losses from this cause.

In subsequent experiments, administration of streptomycin was resorted to in all animals which developed a rise in temperature and a rapid rate of respiration. Only one death (calf 8) occurred among the animals used in the remaining series of investigations. This animal refused food upon arrival and could not be induced to take more than a small amount of food.

A crisis period was observed in about 90 per cent of the calves. This critical period occurred chiefly during the second and third day of life. Once this period was successfully negotiated, an increase in vitality was noted. In the presence of a proper diet, an immediate increase in food intake occurred with a corresponding increase in body weight.

Calves 6, 7 and 9 were maintained on the fat-free synthetic milk 2 for 18, 14 and 6 days, respectively. Except for calf 9, which refused to take more than one-half of the allotted milk during the first week, these animals made gains comparable to the Ragsdale standard (14). In order to test the feeding of fat with phospholipid, these three calves were given 2.5 per cent butter oil, emulsified in the presence of soya lecithin. The abrupt change to fat-containing diet did not cause digestive disturbances in any of the calves nor was any difficulty encountered when they were transferred to whole milk at the end of the experimental period.

Further studies of the effect of phospholipid upon fat utilization were made. Butter oil (3.5 per cent) and soya lecithin were emulsified and fed to calves 10, 11 and 12. These animals responded to the ration much better than the non-fat

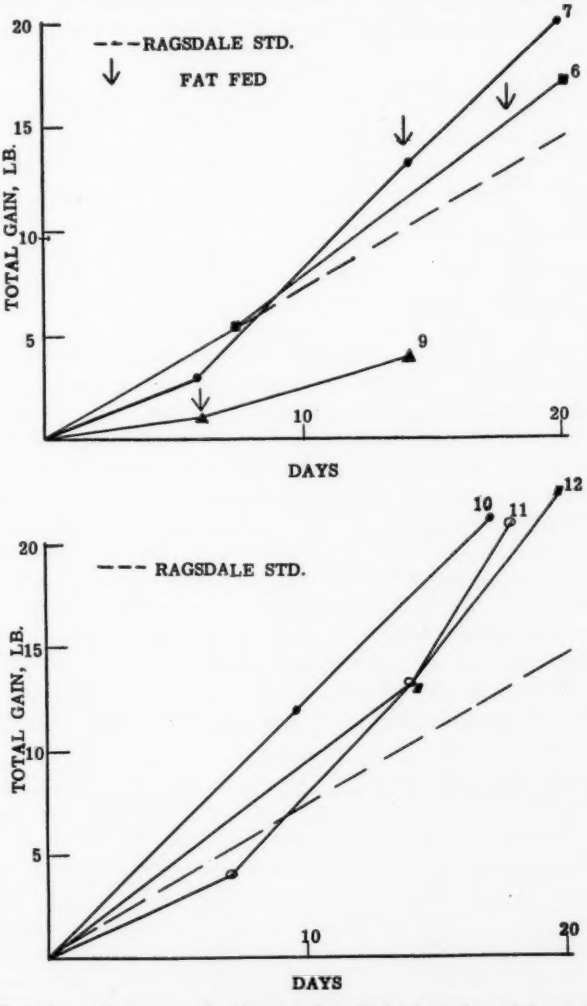

FIG. 1. Growth performance of colostrum-free Holstein calves fed synthetic milk 2. Weight gains in top figure are shown for calves not fed fat until the day indicated by arrow. Lower figure shows growth performance of calves fed milk 2 with butterfat from birth.

control group and made gains considerably higher than the Ragsdale standard (figure 1). Scouring did not develop in any of the calves. They were apparently normal animals.

Blood protein studies made on calves 6, 7, 11 and 12 revealed slight abnormalties. At approximately 2 wk. of age, these animals had serum protein concentrations of 5.0, 5.5, 5.6 and 5.0 g. per cent, respectively, values which appear to be slightly lower than those observed in colostrum and milk-fed calves of similar age. Electrophoretic data summarized in table 5 indicate that the

TABLE 5

Comparison of the distribution of blood serum proteins of calves fed synthetic milk 2 and skimmilk

Age	Diet	% of total blood serum protein			
		albumin	α globulin	β globulin	γ globulin
2 wk.	synthetic milk 2	41.8	30.6	26.8	7.2
Birth	" "	45.2	42.5	9.3	2.5
2 wk.	skimmilk[a]	47.0	30.2	17.9	4.8

[a] Data, Hansen and Phillips (8).

ration gave results similar to those found by Hansen and Phillips (9) in skimmilk-fed calves denied colostrum. Otherwise all other observations indicated that the blood constituents were essentially normal. Blood vitamin A was checked in calf 6 at 14 days of age and found to be 22 γ per 100 ml. of serum.

The excellent performance and gains made by the calves on milk 2 led to further investigations on the importance of rennet coagulation of the milk and of the essentiality of soya lecithin in the utilization of the fat. A diet which was a modification of milk 2 was used in these studies. A series of milks containing various levels and ratios of calcium and sodium was prepared in the same way as milk 2. $NaHCO_3$ was added as a solution to casein suspended in varying amounts of lime water to give milks containing concentrations of sodium from 0.63 to 0.98 g. and levels of calcium from 0.80 to 1.20 g. per liter of synthetic milk. As in the case of milk 2, the pH was adjusted to 6.6. Coagulation times for these milks are shown in table 6 when a 1:50 dilution of

TABLE 6

The effect of variation in levels of Ca and Na in synthetic milk on coagulation by rennet

Milk	Ca g/l.	Na g/l.	Coagulation[a] at 40° C.
milk 1	0.73	0.87	none
milk 2	1.26	0.53	4 min.
test milk	0.80	0.98	none in 2 hr.
" "	0.90	0.98	" " "
" "	1.00	0.98	" " "
" "	1.10	0.98	some in 30 min.
" "	1.20	1.18	3 min.
" "	1.20	1.28	4 "
" "	1.20	1.38	3 "
" "	1.30	1.38	3 "

[a] Commercial rennet at 1:50 dilution.

commercial rennet was added. A calcium content of at least 1.10 g. per liter was necessary before coagulation occurred. A milk similar in composition

to milk 2, except for the calcium and sodium ratio, was selected for study. It contained 0.80 g. of calcium and 0.98 g. of sodium and was designated as milk A. This milk closely approximated milk 1 with respect to the Ca : Na ratio and ion concentrations and, like milk 1, was not coagulated by rennet.

Milk 2 was fed to another group of calves to determine whether cottonseed oil emulsified with soya lecithin would be tolerated similarly to the emulsified butter oil. First, a Guernsey calf (no. 13) was fed milk 2 with cottonseed oil emulsified in a Waring blendor with soya lecithin and water. After 2 days the calf began to show definite indications of diarrhea. Microscopic inspection of the emulsion revealed considerable numbers of large oil globules which were not completely emulsified by the Waring blendor. In order to further reduce the size of the fat globules in the ration of the calf, a mixture of 10 lb. of cottonseed oil in 30 lb. of water containing 400 g. of soya lecithin was emulsified by means of a Gaulin single-action homogenizer at 1800 lb. pressure. The oil-water emulsion was re-cycled through the homogenizer until microscopic examination showed that the oil globules were 2 μ or less in diameter. When 2.5 per cent cottonseed oil prepared in this manner was added to milk 2 and fed to the calf (now 12 days old), the diarrhea was stopped within 36 hr. On the basis of this evidence all other milks containing cottonseed oil were Gaulin-homogenized.

The growth performance of calves 16, 17, 19, 20 and 22 on milk A (Ca : Na of 0.8 : 1.0) and that of calves 13, 18 and 21 which were fed milk 2 (Ca : Na of 2.5 : 1) are shown graphically in figure 2. Two and a half per cent cottonseed oil was included in both milks. The calves fed the low Ca milk lost considerable weight during the first week and only two animals survived. Severe diarrhea was observed beginning at 24 hr. of age and after the animals had received two feedings of this diet. Their appetites remained good for a few days and they consumed all their milk. Calves 16, 17 and 22, however, continued to scour severely, became weak and listless, finally refused food and died a few hours later. Calves 19 and 20 began to rally at 8 to 10 days of age and to gain weight coincident with a decrease in severity of the diarrhea. The condition of these calves was poor, but they were alert and had good appetites.

The response of calves on milk 2 (Ca : Na of 2.5 : 1.0) with cottonseed oil was good. However, calf 21 made slow gains. This calf was very weak at birth. Its knee joints were enlarged and rachitic and there was a large boney growth on its lower jaw. The animal had a poor appetite for the first week and scoured on the seventh and eighth days. It was constipated for the following 4 days, but a marked improvement in appetite and gain in weight were observed following this period. When it was taken off the experiment on the 24th day, the bone abnormality had disappeared and general appearance of the calf was good. Calf 13, after the change to the thoroughly homogenized oil, made rapid gains, did not scour again and appeared normal in every respect. Calf 18 made gains which paralleled the Ragsdale standard throughout the period.

The apparent importance of feeding the very young calf a milk which would coagulate when rennet was added prompted other experiments. Two calves, a

Guernsey and a Holstein, were used in a reversal experiment. Figure 3 shows the growth of the calves used in these studies.

Calf 14 was fed milk A (Ca : Na of 0.8 : 1.0) with cottonseed oil from birth to 8 days of age. Its reaction to the ration was identical to that observed in other animals except that it had less appetite. On the eighth day the ration

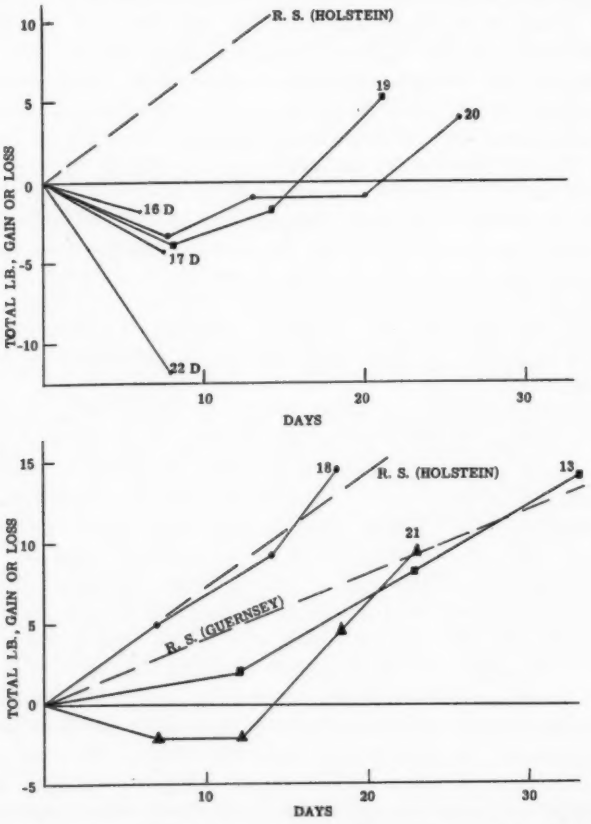

FIG. 2. Growth performance of colostrum-free calves fed synthetic milk with 2.5% cottonseed oil. Upper figure shows growth data of calves fed milk A. (Sodium and calcium concentration in this milk was altered to prevent rennet coagulation.) Lower figure shows growth response of calves to milk 2 with 2.5% cottonseed oil.

Calves number 13 and 16 were Guernsey, calf 19 Ayrshire and the remaining animals Holsteins. Legend: R. S., Ragsdale standard: D, died.

was changed to milk 2 (Ca : Na of 2.5 : 1) with cottonseed oil. The scouring soon stopped and rapid gains in weight followed. The Guernsey (15) was raised to 14 days of age on milk 2 and butter fat before being placed on the milk A with cottonseed oil. Indigestion and scouring did not appear following the change

in diet and the animal continued to make excellent gains in weight. Figure 3 shows that this animal made gains in weight which were much higher than expected on the basis of the Ragsdale standard for Guernseys.

DISCUSSION

From the results of these experiments it is evident that the synthetic milk 2 (Ca : Na of 2.5 : 10) was a satisfactory diet for colostrum-free newborn calves. Calves fed milk 2 grew normally and did not develop diarrhea. Milk A, which was similar in composition to milk 2 except that ratio and concentration of calcium and sodium were altered sufficiently to prevent coagulation by rennet, was not tolerated by newborn calves. Calves fed this milk, without exception, developed severe diarrhea, became unthrifty, and three of five animals died

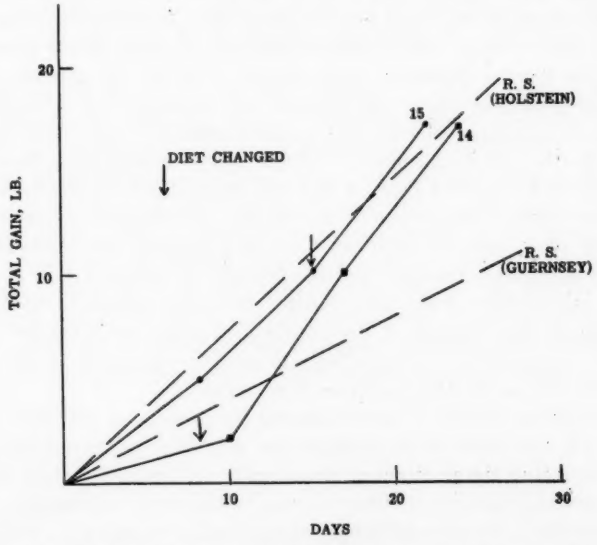

FIG. 3. Weight gains of calf 15 (Guernsey) fed milk 2 with 2.5% butter fat to 14 d. of age then changed to a diet of milk A with 2.5% cottonseed oil. Calf 14 (Holstein) received milk A with 2.5% cottonseed oil for the first 8 d. of life, and then was fed milk 2 with 2.5% cottonseed oil for the remainder of the experimental period.

within a week. However, it was found that a diet of milk A was satisfactory for the 2-wk.-old calf. These facts and the observation that newborn calves which survived on milk A exhibited a gradual decrease in severity of diarrhea and progressive improvement in weight gains with increasing age, clearly indicate that rennet coagulation of milk is essential for the well being of calves during the first days of life. The satisfactory performance of older animals fed milk A can be explained by assuming that the secretion of acid and pepsin in the abomasum was sufficient to cause coagulation of the ingested milk in the older calf.

These considerations are in harmony with other observations and facts. According to Best and Taylor (3), rennin is especially abundant in the gastric mucosa of young animals and pepsin is present in minimal amounts. Since rennin activity is completely abolished in the presence of pepsin at a low pH, one must conclude that rennet coagulation of milk in the stomachs of animals occurs only in a moderately acid environment. On the other hand, pepsin would be inactive in the optimum pH range observed for rennin activity, *viz.* pH 6.0–6.6. That rennin activity cannot be wholly responsible for the coagulation of milk in older calves may be concluded from observations made by Mortenson *et al.* (14). Their investigations on fistulated calves revealed that the hydrogen ion concentrations of stomach contents during curd digestion varied between pH 2 and 3.

With these facts in mind, it is to be concluded that coagulation of milk in the stomachs of calves is of vital importance to the proper digestion and assimilation of this food. This would insure retention of milk in the abomasum and allow time for partial digestion of the casein, globulin and albumin before passage into the intestinal tract. Aside from this consideration it is apparent that the rate of food passage through the gastro-intestinal tract would be markedly influenced by the physical condition of the milk constituents. Semi-solid substances, such as coagulated milk, would not move down the tract as rapidly as liquids. The marked improvement in response of calves to rennet incoagulable milk as they grew older, coincident with an increased development of gastric secretion, is additional evidence that coagulation of ingested milk is an essential step in the assimilation of this food during early life. These facts offer evidence for the delayed development of the pepsin-HCl digestive functions in the calf. Apparently, the newborn calf is wholly dependent on rennin action as a digestive aid until the pepsin-HCl function is developed.

The response of calves to butter oil and cottonseed oil revealed few, if any, differences. It was demonstrated that it was necessary to thoroughly homogenize the cottonseed oil in the presence of soya lecithin to avoid digestive disturbances. However, partially emulsified butter oil was found to be satisfactory.

An explanation for this difference is not readily apparent. While the presence of soya lecithin was essential for the production and subsequent stabilization of the finely divided oil globules in an aqueous medium, the soya lecithin may have made other contributions. It is reasonable to assume that the great increase in the surface area of the oil resulting from the reduction of the oil globules to microscopic dimensions would increase the rate of lipase action and subsequent assimilation of this oil. A study by Augur *et al.* (1) showed that the addition of lecithin to the diet improved the digestibility of cottonseed oil or hydrogenated cottonseed oil in the rat. Diarrhea occurred less frequently among animals fed high fat and lecithin than in the control high-fat group. The beneficial effect of lecithin on fat digestion was explained by suggesting that lecithin increased the rate and degree of fat emulsification. The effect of emulsifying agents on fat utilization by human subjects with nutritional difficulties was studied by Jones *et al.* (12). The marked reduction of stool fats when

Tween 80 was included in the diet is further evidence that surface active agents play an important role in fat utilization. The observations reported by Shantz *et al.* (16) that rats had better hair coats and appeared thriftier when egg lecithin was fed with corn oil and coconut oil also suggest that lecithin enhances fat utilization. Further evidence that lecithin is important in nutrition was indicated by Esh *et al.* (5). They found that addition of lecithin to skimmilk increased the vitamin A blood level in young calves. The fact that Gullickson *et al.* (7) found that vegetable oils homogenized into skimmilk did not make a satisfactory diet for calves may be due to the lack of sufficient amounts of lecithin in skimmilk. The satisfactory response of calves to the cottonseed oil when thoroughly homogenized in the presence of soya lecithin seems to bear this out.

SUMMARY

A semi-synthetic milk coagulable by rennet was developed and found to be nutritionally adequate for colostrum-free calves when streptomycin was administered.

Fat could be fed with this milk without adverse effect. Butter oil emulsified with soya lecithin in a Waring blendor gave better growth results than cottonseed oil similarly dispersed. However, an excellent response to cottonseed oil was observed when the oil was thoroughly homogenized with an aqueous suspension of soya lecithin before addition to the milk.

The distribution of blood serum proteins of animals fed the rennet coagulable synthetic milk was similar to that observed in colostrum-free calves fed skimmilk.

A synthetic milk in which the calcium and sodium balance was altered to prevent rennet action produced severe diarrhea among newborn calves. This milk was a satisfactory diet for older animals. This fact offers evidence for a delayed development of pepsin-HCl digestion function in the calf.

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FERTILITY OF DILUTED BULL SEMEN CONTAINING 100 MICROGRAMS OF STREPTOMYCIN PER MILLILITER[1]

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The recent discovery of antiobiotics has aroused interest concerning their possible use in increasing fertility of diluted bull semen. In 1947, Salisbury and Knodt (8) reported that the addition of sulfanilamide produced increased fertility rates. Almquist (1, 2, 3) has shown that both penicillin and streptomycin increase the fertility rates of certain relatively infertile bulls and with his co-workers (4) has reported that levels of streptomycin above 100 γ per milliliter of diluted semen were especially effective in controlling bacteria. They also showed that levels of streptomycin up to 1,000 γ per milliliter did not significantly decrease sperm livability. It was the objective of this study to test the addition of streptomycin to diluted semen used in routine artificial breeding.

EXPERIMENTAL

All 16 bulls in use at the time by the Connecticut Artificial Breeding Association were subjected to the conditions of the experiment. All 84 ejaculates collected and used during the first 4 mo. of 1949 were utilized in a split-sample type of study.

Semen, after routine collection and examination, was diluted at an average ratio of 1 to 75 in a diluter composed of equal parts egg yolk and sodium citrate (3.6 per cent $Na_3C_6H_5O_7 \cdot 5\frac{1}{2}H_2O$) plus sulfanilamide (0.6 per cent) in sterile distilled water. The diluted semen then was divided into two portions. The first portion served as a control, while to the second portion, 100 γ of streptomycin sulfate were added to each milliliter.

Inseminators were divided into two groups so that each group would inseminate a similar number of cows over a given period of time. Each inseminator group received alternately treated and non-treated samples from each bull.

The per cent of 60- to 90-day non-returns (N. R.) to first service was utilized as the basis of comparison. Consideration was given only to first services in accumulating these data.

RESULTS

A total of 4,719 first services were recorded by the Association during the course of this study. Of these, 2,340 cows were inseminated with control semen and 2,379 with semen containing streptomycin.

When the operation was considered as a whole, the 60- to 90-day N. R. per cent for the control group was 61.1 and for the streptomycin-treated group, 69.8.

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This was an increase of 8.7 N. R. per cent for the 4-mo. period for streptomycin-treated samples.

Differences in N. R. per cent, when converted to angles and weighted as described by Landauer and Bliss (6), showed a highly significant ($P < 0.001$) increase attributable to the addition of streptomycin. In comparison to the actual difference, 8.7 N. R. per cent, the weighted mean difference was 9.7 N. R. per cent. Table 1 shows the raw percentages and differences for the individual bulls.

The response of individual ejaculates to the streptomycin treatment was found to have a definite inverse linear relationship to the level of fertility of untreated samples. This relationship, which is graphically presented in figure 1, can be expressed as $Y = 51.872 - 0.8876X$.

TABLE 1

Percentage of non-returns by bulls

	No. of ejaculates	Without streptomycin	With streptomycin	Difference
Doug	6	67.9	77.6	9.7
Major	8	61.5	65.4	3.9
Judge	6	73.0	78.2	5.2
Norman	5	66.9	64.5	−2.4
Conqueror	2	54.7	59.3	4.6
Kenneth	9	51.7	68.9	17.2
Fayne	5	60.6	74.8	14.2
Prince	8	67.1	66.1	−1.0
Nutmeg	3	65.8	68.6	2.8
Donald	9	47.9	68.2	20.3
Watchman	4	54.7	65.1	10.4
Impressive	11	60.7	69.3	8.6
Commander	2	64.3	89.1	24.8
Avalon	4	63.4	80.4	17.0
Mac	1	36.7	65.2	28.5
Superior	1	44.4	78.3	33.9

DISCUSSION

Mixner (7) reported at the same meeting that a preliminary report of this work (5) was presented that the addition of 1,000 γ of streptomycin plus 1,000 γ of penicillin per milliliter of diluted semen failed to result in a statistically significant increase in fertility. Four possible explanations for the discrepancy between Mixner's report and the data presented here have occurred to the authors. First, the calcium-chloride complex of streptomycin was used in his study, the sulfate salt in this one. Second, the 1,000 γ level treatment with streptomycin may not be as favorable as a lower level. Third, streptomycin alone may be more effective in increasing fertility rates than a combination of streptomycin and penicillin. Fourth, in light of the association between initial fertility and response reported herein there is the possibility that the ejaculates in Mixner's report were of higher initial fertility and would not show as great a response under such circumstances.

The third possibility is supported by a comparative study conducted by Almquist (2, 3) in which semen from some relatively infertile bulls was treated with

streptomycin, penicillin and a combination of both. All treatments produced highly significant fertility increases as compared to controls. Although no statistically significant difference was found between the antibiotics used, the results

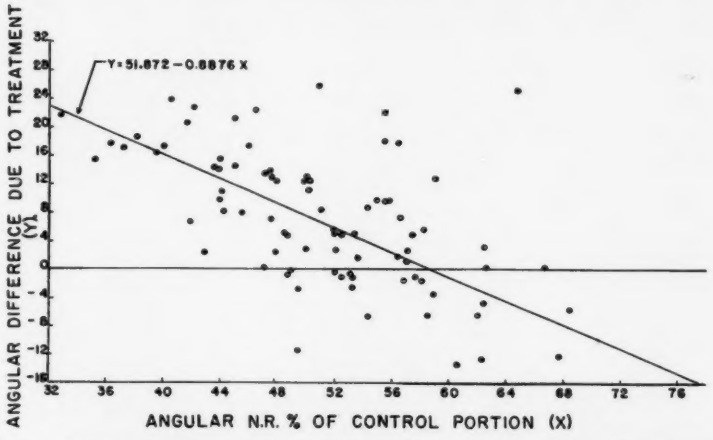

FIG. 1. Linear regression associated with streptomycin treatment of diluted semen.

did show that the percentage of conceptions for the streptomycin-treated semen was somewhat higher than semen treated with penicillin or the two in combination.

SUMMARY

Streptomycin sulfate in the amount of 100 γ per milliliter was added to diluted bull semen used in the routine operation of an artificial breeding establishment on a split sample control basis for a period of 4 mo. A total of 2,340 cows was inseminated with the control semen, and 2,379 cows with semen containing streptomycin.

Over-all results showed a 61.1 N. R. per cent for the control group as compared to 69.8 N. R. per cent for the streptomycin-treated group. The increase of 8.7 N. R. per cent was found to be highly significant.

An inverse linear relationship between response and the initial level of fertility was noted even though most bulls of "so-called" high efficiency responded in some degree to treatment.

ACKNOWLEDGMENT

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THE EFFECTIVENESS OF SOME ANTIFOAMING AGENTS IN THE CONDENSING OF SKIMMILK AND WHEY

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The foaming of skimmilk is a problem encountered in many dairy plant operations. The inherent tendency for skimmilk to foam results in the loss of both product and labor. One of the more obscure problems encountered in processing skimmilk and whey is the formation of large quantities of a very stable foam in the vacuum-condensing operation. The so-called "wild pan," a condition most prevalent in the spring of the year, is characterized by excessive foaming in the vacuum pan accompanied by a "boiling over" into the condensing unit. Ultimately, these milk solids enter the sewage system where their presence constitutes an additional problem of disposal. Although the "wild pan" is not a common experience in the larger commercial operations, the frequency with which this condition is encountered by the small, batch-size pan operator warrants attention.

The phenomenon of foam formation in fluid dairy products has been an object of scientific investigations for many years. Teete (3) and Sanmann and Ruehe (9) observed that milk and skimmilk possessed minimum foaming characteristics at temperatures ranging between 20 and 30° C. They both noted an increase in foam volume and stability at temperatures above 30° C. Rahn and Sharp (6), Ansbacher *et al.* (1), and more recently El Rafey and Richardson (2), as well as numerous other investigators have noted the destabilizing effect of small amounts of milk fat on the foam structure of milk, separated milk and whey. In fact, the practice of adding small amounts of cream or butter to a "wild pan" as a means of breaking the foam has been a common practice among pan operators for many years. Such procedures, however, have not always been entirely satisfactory in alleviating excessive foaming in the vacuum pan.

In other industries, chemical antifoaming agents have been employed to reduce foaming. Ross (7) listed some of the more widely used chemical antifoamants into groups according to their chemical types: alcohols, fatty acids, and fatty acid esters, combinations of amides and fatty acids, ethers, organic phosphates and silicones. These compounds are surface-active materials possessing a positive spreading coefficient and act specifically as anti-foamants when they are insoluble in the continuous phase of the system involved. The object of this paper is to report the results of a study of various antifoaming agents added to skimmilk and whey.

EXPERIMENTAL

A laboratory-model vacuum pan was assembled and is illustrated in figure 1. On controlled operation trials, which consisted of condensing 2 lb. of skimmilk to 27 per cent total solids, performance data scaled to production size pans were obtained. Skimmilk, separated at 95° F., or whey, obtained from a starter and

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rennet set whole milk, was heated in the hot well (*B*) to 160° F. and then admitted slowly to the vacuum flask under a vacuum varying between 25 and 26 in. of Hg. The boiling temperature for normal operating conditions was maintained at approximately 125° F. Under these conditions, 2 lb. of fluid skimmilk could be condensed in 2 hr. The profuse foaming of skimmilk and whey, comparable to that observed in the operation of production units, was induced by increasing the rate of intake into the vacuum flask until the vacuum was lowered from 26

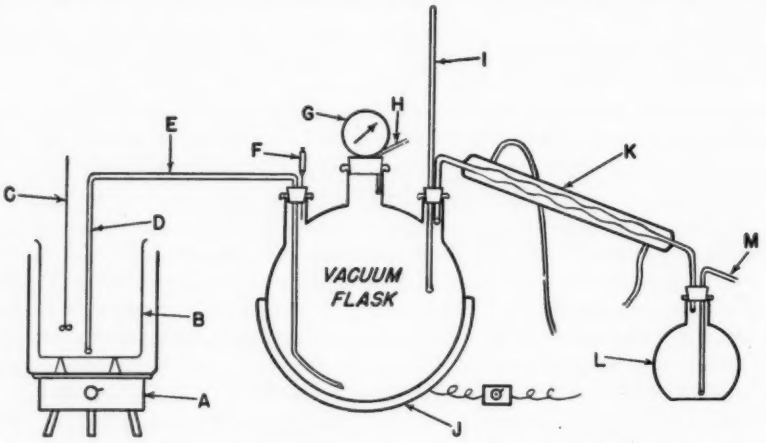

FIG. 1. Diagram of the laboratory-model vacuum pan used in this study.

A. Hot plate
B. Hot well
C. Mechanical agitator
D. Intake to vacuum flask
E. Intake control valve
F. Syringe
G. Vacuum gauge
H. Vacuum release valve
I. Thermometer
J. Glas-Col heating mantle and rheostat control
K. Condenser
L. Water trap
M. To vacuum pump

to 24 in. At this point, the intake was reduced to its normal rate. The rather sudden introduction of a relatively large volume of fluid containing a considerable quantity of dissolved air resulted in the production of copious amounts of a very stable foam, characteristic of foaming conditions observed in "wild pans."

The materials used as antifoaming agents were added directly to the vacuum flask by means of a medical syringe (*F*) protruding through a rubber stopper into the vacuum flask and are listed categorically in table 1 as (*A*) naturally occurring foam depressants and (*B*) chemical antifoaming agents. The naturally occurring materials represent antifoamants obtainable from natural sources which have been used to a limited extent as a means of alleviating excessive foam formation in the vacuum pan. The materials designated as chemical antifoaming agents were selected surface active materials representative of a large group of commercially available antifoaming agents frequently used in industrial operations as a means of combating undesirable foaming.

TABLE 1

The apparent effectiveness of selected antifoaming materials when added to skimmilk and whey in the vacuum-condensing operation

Materials studied	No. of trials	Concentration[a]	Antifoaming action[b]	Remarks
A. Naturally occurring foam depressants		(%)		
1. Milk fat				
a. As butter	2	0.5	+	The slight antifoaming action of butterfat is forfeited when the concentration exceeds 10%. The high fat concentration is conducive to the production of a stable frothy type foam.
	2	2.0	++	
	2	10.0	0	
b. As fresh cream	3	0.5	+	
	2	2.0	+	
	2	10.0	0	
c. As rancid milk and/or cream	3	0.05	++	Very effective antifoaming action was noted. A slightly bitter flavor was detected in the highest concentration.
	2	0.1	++++	
	2	2.0	++++	
B. Chemical antifoaming agents				
1. Water insoluble materials				
a. Silicone compound	2	0.01	++++	Very effective and persistent antifoaming action. Off-flavor slightly perceptible in highest concentration.
	2	0.05	++++	
	2	0.10	++++	
b. Mono and diglyceride mixtures (glyceryl esters of stearic acid)	2	0.05	++	Dispersed in skimmilk at 160° F. Very effective antifoaming action except in lowest concentration. No off-flavor.
	2	0.1	+++	
	2	0.2	++++	
c. Sorbitan monolaurate	2	0.1	+	Antifoaming action not persistent in lower concentrations. No off-flavor detected.
	2	0.3	++	
	2	0.5	++++	
	2	1.0	++++	
d. Octyl alcohol (2-ethyl hexanol)	2	0.01	++	Very effective antifoaming action was noted. Antifoaming tendency was not persistent. Sweet flavor detected in finished product.
	2	0.1	++++	
2. Water soluble materials				
a. Butyric acid	3	0.05	++	Antifoaming action accompanied by a general precipitation of the foam-film.
	2	0.1	+++	
b. Quaternary ammonium chloride (cationic)	2	0.05	0	Antifoaming action accompanied by a partial precipitation of the foam-film.
	2	0.1	++	
c. Alkyl-aryl sulfonate (anionic)	3	0.1	0	Foam formation is enhanced.
	2	0.5	−	
d. Polyoxyethylene sorbitan monolaurate (nonionic)	2	0.1	0	Foam formation is enhanced.
		0.5	−	

[a] Concentrations of antifoaming materials were based upon the initial weight of fluid skimmilk or whey.

[b] Antifoaming action was judged by observation and assigned relative values according to the following legend:

− increase in the foaming tendency
0 no apparent antifoaming action
+ slight antifoaming action
++ moderate antifoaming action
+++ pronounced antifoaming action
++++ very effective antifoaming action

In addition to the effectiveness of these materials as antifoaming agents in the vacuum-condensing of skimmilk and whey, their use also was noted relative to the physical appearance and flavor of the finished product. For this purpose 0.5-pt. samples of the condensed product were stored at 45° F. for 24 hr. prior to judging for flavor defects. Flavor criticisms were made by two judges working independently.

RESULTS

Data and pertinent observations relative to the use of both naturally occurring foam depressants and chemical antifoaming agents in the alleviation of excessive foaming during the vacuum-condensing of skimmilk and whey are presented in table 1.

DISCUSSION

Surface activity in itself apparently is not sufficient evidence for assigning antifoaming properties to chemical substances, although Ross (7) stated that nearly every type of surface active material will act as an antifoamant if appropriately used. Whether or not the substance is soluble in the water phase is, obviously, of more significance in evaluating the antifoaming characteristics of a compound than is the relative surface activity as expressed in dynes per cm^2. Parkhurst (5), studying the foaming characteristics of various surface active materials, advanced the thought that foam stability is not a function of low surface tension, as such, but rather of the adsorbed layer giving rise to the lowering of surface tension. Any postulation advanced to explain adequately the specific behaviors of surface active antifoaming agents must, therefore, include not only a consideration of surface activity but also the solubility characteristics, the nature of ionization and the electrostatic charge and other constitutive properties of the compound.

The ineffectiveness of water-soluble, anionic and nonionic surface active materials as antifoamants conceivably might be accounted for if it is assumed that the surface-active anions or nonionic molecules are oriented at the air/liquid interface (foam-film) in a definite scheme compatible with the surface active milk proteins. In fact, the addition of materials of this nature enhance the formation of a stable film and make possible the production of a foam showing greater volume and stability. If the stability of the foam structure is dependent upon the orientation of surface-active materials at the air/liquid interface, an assumption generally supported by existing evidence concerning the nature of foam formation, then any surface-active substance possessing characteristics opposed to those of the materials making up the foam membrane will disrupt the orientation pattern and cause the foam structure to disintegrate. Evidently, this was the result when a surface-active, cationic quaternary ammonium compound was added to the skimmilk. This compound is water-soluble and completely ionized with the surface-active ion bearing a positive charge. When this positively charged ion is oriented into the foam-film at the air/liquid interface in proximity with the negatively charged, surface-active milk protein, there exists a tendency for the mutual attraction of these ions which results in the partial precipitation of the protein

material and finally a collapse in the foam structure. The complete degeneration of the foam structure and the partial precipitation of the milk proteins upon the addition of small concentrations of butyric acid to the vacuum flask is explained in a similar manner. The positively charged hydrogen ions disassociated from butyric acid discharge the negatively charged protein sol causing it to precipitate into a gummy mass which inhibits the formation of foam. These characteristic behaviors of water-soluble surface-active materials when added to skimmilk or whey in the vacuum flask preclude the use of such materials as antifoaming agents.

The fact that all of the effective antifoaming materials studied in this work were water-insoluble, surface-active substances suggests the probability that these compounds are antagonistic to the systematic orientation of the milk proteins, presumably necessary for the formation of an elastic film, and consequently, a stable foam structure. Being water insoluble, molecular aggregates of these substances tend to displace the less surface-active milk proteins at the air/liquid interface. Since there is no tendency on the part of molecules of these antifoaming agents to arrange themselves into a definite pattern and an elastic film, the foam structure is broken.

The foam depressing effectiveness of milk fat in fresh cream or butter usually is attributed to the ability of free or globular fat, when carried into the foam lamella, to establish weak points which cause a collapse of the foam structure. This reasoning, however, cannot account for the increased foaming tendency of high fat creams. Neither can the decidedly increased antifoaming activity of much smaller amounts of rancid milk and cream be accounted for in this manner, but rather, on the basis of the substances produced as a result of enzymatic hydrolysis. Probably the most significant substances produced by enzymatic hydrolysis of triglycerides from the standpoint of antifoaming activity are the mono and diglyceride mixtures and free fatty acids. In view of the results obtained in this study with butyric acid, it is assumed that the presence of the water soluble, short-chain, fatty acids cannot account for the antifoaming activity of rancid milk fat. If butyric or other of these low molecular weight acids were liberated in any appreciable quantity, their disassociation would build up the hydrogen ion concentration to the point where a general precipitation of the foam-film would occur. The fact that such a precipitation did not result from the addition of small portions of rancid milk and cream enables us to discount the antifoaming action attributed to this class of fatty acids. On the other hand, the presence of the longer chain, water-insoluble acids as well as the residual mono and diglyceride mixtures, compounds possessing known antifoaming properties, probably explains the antifoaming effectiveness of rancid milk and cream.

All of the chemical antifoamants used successfully in this study, with the exception of the silicone, consisted of components found in combined or uncombined states in many common edible foods. Silicone compunds are non-toxic, however, when used in concentrations recommended by Rowe *et al.* (8). At the present time, many of the fatty acid esters find a popular use as emulsifiers in ice cream but they could serve a double purpose if they were added to skimmilk,

prior to condensing for serum-solids, to control excessive foaming in the vacuum pan.

SUMMARY

A laboratory model vacuum pan, designed to give operational performance comparable with production size units, was employed to study the effectiveness of various materials as antifoaming agents in the condensing of skimmilk and whey.

Milk, cream and butter as well as selected surface-active, chemical compounds were added to skimmilk and whey during the condensing operation. Cream and/or butter were moderately effective as foam depressants. Slightly rancid milk and/or cream were extremely effective foam inhibitors. Of the chemical antifoaming agents studied, the silicone compound, mono and diglyceryl esters of stearic acid and sorbitan monolaurate constitute those used most effectively to eliminate the excessive foaming tendency of skimmilk and whey. These materials are water insoluble, surface-active substances.

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THE EFFECTS OF FEEDING PARATHION TO DAIRY COWS[1, 2]

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The increasing use during the past few years of synthetic organic chemicals for the control of insects on forage crops has led to considerable concern about the persistency of residues of these materials and the possible excretion of these chemicals in the milk. The appearance of DDT and related chlorinated hydrocarbon insecticides in the milk of cows whose diets included small amounts of these materials has been established (2, 4, 5, 6, 7, 12, 13, 14, 15, 17, 18). This contamination of milk has been the basis for certain precautions with regard to the use of DDT and related insecticides on forage crops that might be fed to lactating cows.

The organic phosphate insecticide known as parathion, 0,0-diethyl 0-p-nitrophenyl thiophosphate, possesses several unusual chemical and insecticidal properties. This material originated in Germany and subsequently has been produced commercially in this country. Parathion has proved to be effective in controlling a large number of insects and related arthropods. It has been demonstrated that amounts of parathion necessary for satisfactory insect control on such crops as peas, corn and alfalfa usually result in parathion residues of less than one part per million when analyzed 1 wk. or more after the last parathion application (1, 8, 9, 10, 11). Its insecticidal value is marred only by its high toxicity to warm-blooded animals. Because of the widespread use of parathion as an insecticide on crops which subsequently are fed to dairy animals, it was considered important to determine whether parathion included in the diet in amounts comparable to that which has been found as a residue on foliage would appear in the milk of dairy cows.

PROCEDURE

Ten cows, including two Holsteins, four Guernseys, two Jerseys and two Ayrshires in mid-lactation were allotted to two equal groups on the basis of breed, stage of lactation and milk production. All cows were on good sudan, brome or rye pasture during the experiment. Atlas sorgo silage was fed at a level of 2 lb. per 100 lb. body weight, and the cows had access to alfalfa hay during the time of day when they were not on pasture. A grain concentrate mixture containing approximately 16 per cent crude protein was fed according to milk production. Cows in group I were fed commercially available parathion in the form of a 25 per cent wettable powder at the level of five parts per million of the estimated dry matter intake of the roughage in the ration. Cows

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in group II were fed parathion at the level of one part per million of the estimated roughage dry matter intake. The parathion was administered daily in capsules. Since forage crops treated with amounts of parathion for good insect control usually contain residues of less than one part per million, the feeding levels used in this study represent an intake of parathion greater than that which normally would be ingested with parathion-treated roughage. The maximum roughage dry matter intake of the cows was estimated to be 2.25 lb. per 100 lb. of body weight. On this basis, cows in group I were fed 0.112 mg. of parathion per kilogram of body weight, and cows in group II were fed 0.022 mg. of parathion per kilogram of body weight. All cows were weighed on 3 consecutive days at bi-weekly intervals. The average of these weights was used as the basis for calculating the parathion dosage for the ensuing 2 wk.

Ten of the cows were fed parathion continuously for 81 days. In order to study the effects of parathion feeding on cows producing small amounts of milk, two Ayrshires in the terminal 2 wk. of lactation were allotted to the two groups. These two cows in late lactation were fed parathion for only 14 days. At the termination of the 81-day period, the feeding level of two cows from group I, a Guernsey and an Ayrshire, was increased immediately to 10 parts per million of parathion on the same basis. Then, the amount of parathion fed was doubled each succeeding week until the cows were ingesting 40 parts per million daily. At this final level, which was fed for 1 wk., the cows were receiving approximately 0.9 mg. of parathion per kilogram of body weight daily.

Samples of carefully mixed milk were taken on alternate days for 6 days before the beginning of the parathion-feeding experiment and on alternate days for 6 days following the first feeding of parathion; after this, samples were taken twice weekly for 3 wk. Thereafter, samples were taken once a week for the duration of the experiment. The milk from the Guernsey and Ayrshire cows from group I, which were fed the higher levels of parathion, was sampled and analyzed twice weekly during the 3-week experiment.

Samples of milk from each cow were taken at frequent intervals and examined organoleptically to determine whether the feeding of parathion as a supplement to an otherwise normal ration would result in any detectable off-flavor in the milk.

ANALYTICAL PROCEDURE

Application of the sensitive colorimetric method of Averell and Norris (3) for estimating small amounts of parathion was tried on 100-g. samples of milk to which known amounts of parathion were added; extraction attempts were made using the methods developed by Schechter *et al.* (13) and Carter (5). The presence of interfering substances and a very low recovery of the parathion added to the milk did not permit the use of either of these established extraction methods. Upon the suggestion of Averell and Norris of the American Cyanamid Co., a new procedure was tried involving the use of a liquid-liquid extraction apparatus (fig. 1). Essentially, this procedure involves a prolonged percolation of petroleum ether through a column of milk and ethyl alcohol. The mixture in the extraction chamber was stirred at 30-min. intervals with a

wire-loop stirrer inserted through the Liebig reflux condenser. The liquid-liquid extraction procedure was carried out for an optimum period of 6 hr.

Details of the modified analytical procedure are as follows: A mixture of 100 g. of milk and 100 ml. of 95 per cent ethyl alcohol was placed in the liquid-liquid extraction apparatus. A pinch of NaCl, reagent grade (approximately 0.5 g.) was added to the milk mixture to prevent emulsion formation in the extraction chamber and the overflowing of milk solids into the Erlenmeyer

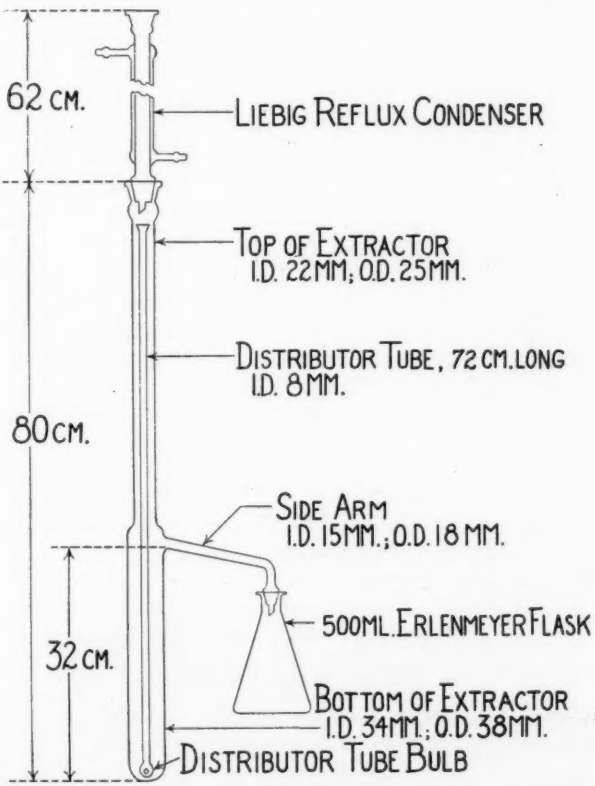

FIG. 1. Extraction apparatus for the determination of parathion in milk.

flask; 150 ml. of technical petroleum ether (Skellysolve "B") were placed in the 500 ml. Erlenmeyer flask of the extraction apparatus. After the assembled extraction apparatus was mounted, the petroleum ether in the Erlenmeyer flask was heated to gentle boiling with a 175-watt hot plate. The extraction process was carried on for 6 hr.; this was found to be the optimum time for best recovery of parathion. The solution in the extraction chamber was stirred at 30-min. intervals with the wire-loop stirrer.

After the extraction was completed, the petroleum ether was transferred to a 150 ml. beaker and evaporated almost to dryness on a warm water bath; a gentle stream of air passing over the liquid facilitated this process.

After evaporation, 20 ml. of 95 per cent ethyl alcohol, 20 ml. of water, 2 ml. of 5 *N* HCl and 0.2 g. of zinc dust were added. The beaker was covered with a watch glass and heated to gentle boiling for 10 min. The beaker was allowed to cool, then the watch glass was washed with distilled water; 25 ml. of petroleum ether were added to the beaker and the solutions swirled around gently to

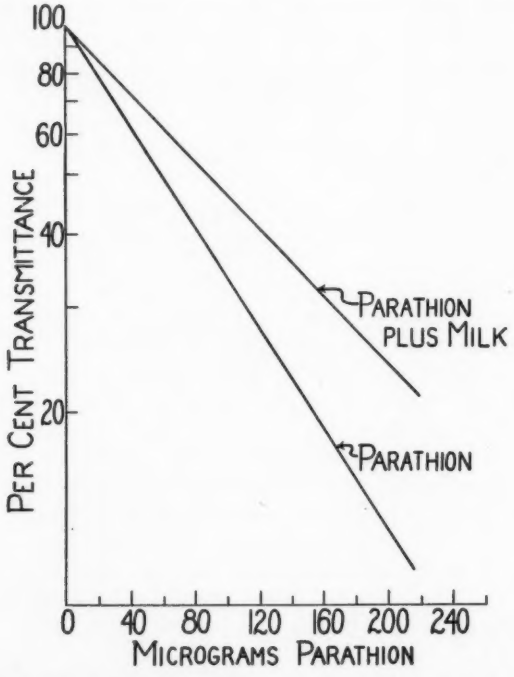

FIG. 2. Parathion standardization curves (Averell and Norris Method, 1948); calibration curves at 555 mμ using a Coleman Model 14 Spectrophotometer.

extract the fat. The ether layer was siphoned off and the extraction was repeated twice more, using 25 ml. of petroleum ether each time. After the third extraction, the last traces of petroleum ether were evaporated by means of a gentle stream of air. The solution then was filtered through no. 42 Whatman filter paper into a 50-ml. volumetric flask. The subsequent steps in the procedure were exactly the same as those reported by Averell and Norris (3).

Standard curves were prepared from the data obtained by adding known amounts of parathion (98.2 per cent parathion), ranging from 20 to 200 γ, to 100-g. samples of milk. The per cent transmittance values were obtained using a wave length setting of 555 mμ with a Coleman model 14 spectropho-

tometer. Standard curves for parathion and milk plus parathion, obtained by using this procedure, are shown in fig. 2.

Technical petroleum ether (Skellysolve "B") was used in all the analyses, since it was found that the use of petroleum ether purified according to the method reported by Werner (16) did not improve the results. Use of 95 per cent ethyl alcohol and distilled water to dissolve the residue remaining after evaporation of the petroleum ether prevented the formation of a turbidity that developed when benzene was used. Any slight turbidity appearing upon the addition of water to the solution of the residue dissolved in ethyl alcohol either disappeared during the reduction process or was removed by filtration.

Milk blanks varied from 95 to above 100 per cent transmittance when compared with the reagent blanks; therefore, in the actual analyses no reading above 90 per cent was considered significant. It can be seen from the standardization curves for parathion plus milk that a transmittance reading of 90 per cent using a 100-g. sample of milk would represent less than 0.2 of a part per million of parathion.

RESULTS

Approximately 250 separate analyses for parathion in the milk from parathion-fed cows were made during the course of the experiment. At no time was any parathion found in the milk from any of the cows fed parathion. These results were checked further by biological assays of the milk from the parathion-fed cows using adult houseflies (*Musca domestica*). The absence of any mortality among the flies served to confirm the negative analytical findings. Referee samples of milk from the parathion-fed cows were frozen and sent by air express to the Stamford, Conn., laboratories of the American Cyanamid Co. for analysis, where essentially the same analytical procedures were used. The results obtained in that laboratory also indicated that no parathion was found in the milk from cows fed parathion at a level of 5 ppm. of the dry roughage intake. A detailed description, treatment and response, of each of the cows fed parathion is shown in tables 1 and 2.

The organoleptic examinations of milk from the parathion-fed cows did not reveal any flavor defects that might be caused by the parathion.

The amounts of parathion administered to the experimental cows apparently had no deleterious effect on their health. Their appetites remained good and their general condition was such that there was no indication of toxic effects of the chemical. Cow no. 458A, a Guernsey that received the high levels of parathion in the final week of the experiment, became lame in her shoulder during the week in which she received parathion at the rate of 40 parts per million of the estimated roughage dry matter intake. In the opinion of the attending veterinarian the lameness was caused by a bruise. Since the cow's appetite remained normal, and her eyes bright, it was felt that the lameness probably was not caused by parathion. The absence of symptoms in the other cows would seem to support the contention that parathion did not cause the lameness.

TABLE 1

Description, treatment and response of cows fed parathion for 81 consecutive days.

Group and no. of cow	Breed	Av. daily milk prod.	Days in lactation at beginning of expt.	Av. weight	Average estimated daily roughage dry matter intake	Av. daily parathion intake	Parathion intake as ppm. of estimated roughage consumed	Av. daily parathion intake per kg. of body weight	Ratio parathion intake to kg. milk produced	Parathion recovered in milk
		(*lb.*)		(*lb.*)	(*lb.*)	(*mg.*)	(*ppm.*)	(*mg.*)	(*mg./kg.*)	(*ppm.*)
Group I										
122A	Holstein	37.7	177	1429	32.1	72.8	5.0	0.112	4.25	0
458A	Guernsey	25.8	152	1037	23.3	52.9	5.0	0.112	4.52	0
451A	Guernsey	26.6	160	1023	23.0	52.2	5.0	0.112	4.32	0
378A	Jersey	24.8	111	896	20.2	45.7	5.0	0.112	4.06	0
200A	Ayrshire	14.4	130	971	21.8	49.4	5.0	0.112	7.54	0
271A[a]	Ayrshire	16.0	234	1026	23.1	53.0	5.0	0.113	7.28	0
Group II										
133A	Holstein	45.5	161	1332	29.9	13.3	1.0	0.022	0.64	0
469A	Guernsey	28.2	131	1100	24.8	11.0	1.0	0.022	0.86	0
465A	Guernsey	27.3	153	1025	23.1	10.2	1.0	0.022	0.82	0
358A	Jersey	22.3	95	846	19.0	8.4	1.0	0.022	0.83	0
246A	Ayrshire	29.7	121	1150	25.9	11.5	1.0	0.022	0.85	0
268A[a]	Ayrshire	10.7	364	1137	25.6	11.0	1.0	0.021	0.95	0

[a] Parathion fed only during the terminal 2 wk. of lactation.

TABLE 2

Description, treatment and response of two cows fed parathion daily in amounts increased at weekly intervals from 5 to 40 ppm.

No. of cow	Breed	Week of feeding	Av. daily milk prod.	Av. weight	Average estimated daily roughage dry matter intake	Av. daily parathion intake	Parathion intake as ppm. of estimated roughage consumed	Av. daily parathion intake per kg. of body weight	Ratio parathion intake to kg. milk produced	Parathion recovered in milk
			(*lb.*)	(*lb.*)	(*lb.*)	(*mg.*)	(*ppm.*)	(*mg.*)	(*mg./kg.*)	(*ppm.*)
458A	Guernsey	1	20.7	1061	23.9	54.1	5.0	0.112	5.8	0
.....	.....	2	20.2	1060	23.9	108.2	10.0	0.225	11.8	0
.....	.....	3	19.0	1068	24.0	216.2	20.0	0.446	25.1	0
.....	.....	4	17.2	1068	24.0	432.4	40.0	0.892	55.4	0
200A	Ayrshire	1	10.8	983	22.1	50.1	5.0	0.112	10.2	0
.....	.....	2	9.5	972	21.9	100.2	10.0	0.227	23.2	0
.....	.....	3	8.9	975	21.9	198.3	20.0	0.452	49.1	0
.....	.....	4	7.9	975	21.9	396.6	40.0	0.897	110.8	0

All of the cows gained slightly in body weight during the course of the experiment (fig. 3); such weight gains are to be expected in cows in that stage of lactation. It is apparent, therefore, that parathion in the amounts fed had no apparent effect on body weight.

Average milk production of the cows in both groups is shown also in fig. 3. Cows in group I had been in lactation an average of 146 days and those in group II, 132 days, at the beginning of the experiment. The slope of the lactation curves is normal for cows in the latter stage of lactation. At the levels fed it would seem that parathion had no deleterious effect on milk production

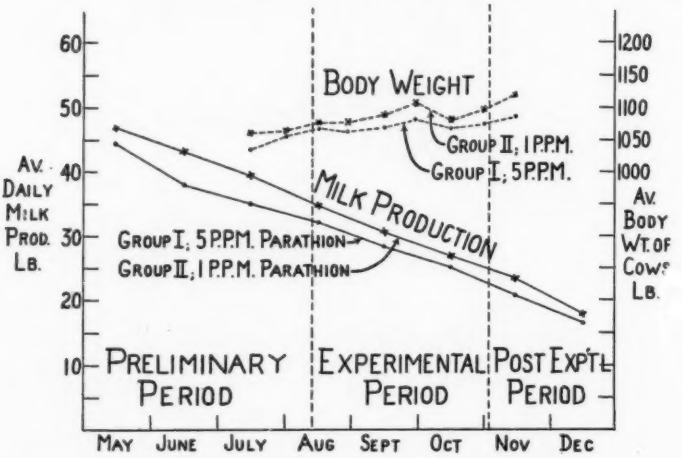

FIG. 3. Average monthly milk production and body weights of cows.

Of the 12 cows used in the experiment, eight were pregnant before parathion was fed and three were bred and conceived shortly after the trial started. The remaining cow came into heat regularly, but was not bred. All pregnancies have been normal and all calves born have been strong and vigorous at birth.

DISCUSSION

Parathion is being used successfully as an insecticide on forage crops at the rate of 0.5 lb. or less of actual parathion to the acre. Under these conditions of use, normally several days will elapse between the application of parathion for insect control and harvesting the crop. A review of published data pertaining to parathion residues either in or on crops such as alfalfa, beans, inner leaves of cabbage, corn leaves, corn stalks, whole peas and pea vines reveals no case where parathion was found to exceed one ppm. of the plant involved when the analyses were carried out from 7 to 21 days after the last application of parathion (1, 8, 9, 10, 11). Furthermore, directions for using parathion explicitly caution against applying the insecticide to crops later than 30 days before harvest.

At the rate of 22.5 lb. of dry matter ingested daily per 1000 lb. of body weight, a dairy cow would consume the equivalent of 90 lb. of fresh green alfalfa. Such a quantity, with a residual parathion rate of one ppm., would cause the intake of parathion to be approximately 40 mg. daily. This does not take into consideration the highly volatile nature of parathion which has been established by residue analyses following the application of parathion to forage crops (8, 9, 11). Therefore, it might be expected that much less than the approximately 40 mg. of parathion present in the freshly cut alfalfa would be present when the hay was consumed. The one ppm. parathion residue on alfalfa therefore is less than the amount ingested by the experimental cows which were fed at a level of 5 ppm. of the estimated dry matter consumed. Also, two of the cows were fed more than eight times that amount for 1 wk.

The fact that the health of the cows seemed unimpaired at any of the dosages used or any cumulative ill effects resulted from rather extensive feeding periods seems to indicate rather conclusively that the crops sprayed with parathion at the usual rates for insecticidal purposes are not made unsafe for livestock feed.

The possibility of deleterious amounts of parathion in the milk produced by such fed animals is a more critical question. By the analytical methods used no parathion was recovered in any of the milk from the cows fed at different known levels, some of which were excessive. The efficacy of the analytical method might be questioned as a precautionary measure by health officials. However, the fact that the milk was tested biologically by feeding it to houseflies with no measurable effect seems to clinch the fact that the parathion was not coming through into the milk.

Two other facts seem worthy of mention. First, the experimental periods involved gave no evidence of cumulative effects on the health of the animals or their milk production. Second, the ratio of parathion fed to milk secreted varied from 0.64 mg. of parathion per kilogram of milk to nearly 12 times that amount in the lower-producing animals. These facts further indicate the reasonable safety of using milk from such parathion-fed dairy cows.

Since the parathion intake of the animals was controlled for extensive periods at what seemed to be higher than expected levels and since no parathion was recovered in the milk at any time, one might raise the question as to the fate of the parathion in the animal body. The authors obtained no data to answer this question. Research pointed toward answering this question not only would be of scientific interest but might establish further the relative safety of using feed containing parathion, provided it could be established that the parathion, or much of it, could be accounted for in other secretions of the body.

SUMMARY

An experiment was designed to determine the presence or absence of parathion in the milk of dairy cows fed parathion in capsules. Ten dairy cows in heavy lactation, representing four of the major breeds, were allotted into two groups and fed a commercially available wettable powder formulation of para-

thion at levels of five ppm. and one ppm., based upon an estimated roughage dry matter intake of 2.25 lb. per 100 lb. of body weight daily, continuously for 81 days. These feeding levels represent an actuaul parathion intake of 0.112 mg. of parathion per kilogram of body weight for the cows receiving five ppm. of parathion, and 0.022 mg. of parathion per kilogram of body weight for the cows receiving one ppm. of parathion based upon the estimated roughage dry matter intake. At the conclusion of this experiment, two of these cows were fed increasing amounts of parathion up to 40 ppm. of the estimated roughage dry matter intake. In neither experiment was any parathion found in the milk of the experimental cows by the use of both a chemical method of analysis for parathion and biological assay using adult houseflies. No objectionable flavor was noted in the milk and no harmful effects to the health or reproductive ability of the cows were observed.

ACKNOWLEDGMENTS

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MILK FEVER (PARTURIENT PARESIS) IN DAIRY COWS—A REVIEW

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Milk fever (parturient paresis) is an afebrile disease which typically is associated with parturition and beginning lactation. It is characterized by a sudden paralysis, gradual loss of consciousness and, if untreated, usually terminates in death. Few diseases of livestock have caused as much theoretical controversy and interest as has milk fever. Gradually, through the years, much has been learned about the nature of milk fever, and effective means of treatment have been devised, resulting in a reduction in mortality of from 60 to 70 per cent to less than 1 per cent. The basic physiological cause of milk fever has yet to be proven. The "parathyroid deficiency (hypocalcemia) theory" of Dryerre and Greig (54) seems to come the nearest of the many theories that have been advanced to accounting for the immediate cause, but many fundamental questions remain unanswered.

EARLY HISTORY

According to Fish (62) it is safe to assume that no such disease as milk fever existed two or three centuries ago. Hutyra and Marek (125) state that the time when the disease became known corresponds with the period when it became customary to feed cows more generously with the object of increasing milk production.

As intensive feeding and selection for higher milk production increased, the number of milk fever cases also increased until by the middle of the 19th century numerous publications on the subject by veterinarians were appearing in the literature from nearly all civilized countries. Hutyra *et al.* (126) have pointed out that milk fever was first mentioned in the literature in Germany by Eberhardt in 1793. Price (Hutyra *et al.*, 126) refers to milk fever in 1806 in his book "The New Useful Farrier and Complete Cow Leech." Skellet (Hutyra *et al.*, 126), an English veterinarian, gave a good clinical description of the disease in 1807, and it was particularly discussed by Jorg in 1808. According to Hutyra *et al.* (126), milk fever first was mentioned in French literature as late as 1837 by Fabre in his "Veterinaire Compagnard."

The treatment of milk fever in the early days was a reflection of the popular medical treatments of the period. Price (1806) (Hutyra *et al.*, 126) recommended sweating by the use of hot packs and blanketing. In 1814, Clater (38) recommended bleeding (4 to 5 qt. 8 to 10 days before calving) as a preventive measure. The following drink was recommended as a preventive to be given at night before turning out to pasture: 1 oz. alum, 1 oz. nitre, 1 oz. cream of tartar, 4 tablespoonsful treacle; after mixing, add to this 1 qt. of boiling ale and beer mixed; 2 hr. after giving, the beast can be turned out.

Boeriche (31) in quoting Blaine, "Veterinary Art," p. 296, says, "The treat-

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ment of milk fever in the early stages alone calls for bleeding and that liberally." He also advised "a plenty of most powerful medicines." On the other hand, he quotes Gamgee ("Dairy Stock" Edinburgh 1861, p. 72) as saying "Above all things avoid strong remedies and bleeding. Either method seems equally unsuccessful, for nearly all die that are taken, according to the testimony of allopathic veterinarian surgeons." He recommends Belladonna (ten drops) and Nux Vomica.

In 1879, Tellor (245) indicated that veterinarians were beginning to question whether or not milk fever and mastitis were synonymous. He recommended stimulants, purges, pouring cold water on the head and chloral hydrate to quiet excitable cases.

Navin (166), in 1872, attributed milk fever to an inflammatory disease of the womb or the peritoneum covering it. "Prompt and copious bleeding is the sheet anchor in this disease," plus sedatives. He also recommended rubbing the cold legs with cayenne pepper and alcohol.

Williams (271) in 1884 attributed milk fever to congestion of the brain and apoplexy associated with heavy milk production and parturition. As treatment he recommended bleeding to prevent congestion of the brain, physics, stimulants, etc. A statement of Williams' aptly expresses the seriousness of the disease to dairymen prior to the classical discovery of the udder inflation treatment in 1897 by Jurgens J. Schmidt of Kolding, Denmark (209). Williams says, "I may state in conclusion that parturient apoplexy (milk fever) is a recurring disease and that it is not safe to allow a cow to calve after it has once been down; and if the owner consults his own interests he will milk it as long as possible and then prepare it for the butcher."

MILK FEVER THEORIES

As is the case with most diseases whose cause is mysterious, numerous theories have been advanced from time to time to explain the etiology of milk fever. Many of these theories, when viewed in retrospect, appear ridiculous in the light of our present knowledge of the disease. However, these theories attracted wide attention at the time of their publication, and through study and observation, the false hypotheses gradually were eliminated. This process led to the present day understanding of the nature of milk fever as set forth in Dryerre and Greig's theory of parathyroid deficiency (hypocalcemia) (54) published in March, 1925, and confirmed by experimental evidence by Little and Wright (147) in May, 1925.

At this point it would seem desirable to summarize briefly the numerous theories that have been advanced in explanation of the etiology of milk fever ("the disease of theories"). The names of these theories, their chief adherents and a brief statement of their bases are as follows:

(1) *General inflammation.* Clater (39), Delabere Blaine (28), Youatt (275), Harrison (100) and Hering (114). This early theory attributed milk fever to congestion and inflammation, especially of the udder and brain. Bleeding and cold packs were recommended as a cure.

(2) *Derangements of the nervous system.* Contamine (42), Friend (73), Robinson (200), Ralph (194), Kohne (135), Rychner (204), Stewart (237), Binz (27), Füsch (74), Röll (203), Baumeister-Rueff (21) and Gunther and Felizet (95). The paralysis of milk fever was thought to be caused by some mysterious derangement of the nervous system.

(3) *General circulatory disturbances.* Bredo (35), Pomayer (181), Kreutzer (137) and Seitter (222). According to this theory, the symptoms were due to low blood pressure brought on by an alteration of certain vasomotor centers. Udder insufflation was thought to act by relieving the low blood pressure.

(4) *Cerebral anemia.* Franck (69), Glass (79), Haubner (110), Wermer (261), Prehr (189), Aronsohn (11), Baroni (18), Zoppini (277), Dommerhold (53), McConnell (151), Billings (26), Hess (115), Meier (156), Sonnenberg (234), Gratia and van den Eeckhout (84), Spiegel and Spiegel (235) and Zehl (276). Cerebral anemia supposedly was caused by the increased supply of blood to the udder. Air insufflation of the udder was thought to relieve the situation. Hutyra and Marek (125), however, were unable to produce milk fever symptoms by removing as much as 44 per cent of all the blood from a cow.

(5) *Cerebral congestion.* Violet (254), Barlow (17), William Williams (270), Sanson (206), Cox (44), Barron (19), Noquet (173), Campbell (36), Ayrault (15), Trasbot (249) and Denenbourg (51). The treatment advised by those who accepted this theory was profuse bleeding, pouring cold water on the head, etc. The symptoms were attributed to congestion of the brain with blood.

(6) *Apoplexy.* Thacker (246), Festal (60), Bragnard (32), Coenraets (40), Walley (257), Beart Simonds (223), Ward (259), Devleeshower (52), Whincop (263) and Gerrard (76). From this theory developed the name parturient apoplexy, often used in early days to designate milk fever. It was believed that the paralysis was caused by cerebral hemorrhage (apoplexy).

(7) *Thrombosis.* Layman (142), Cox (43) and Wild (269). Milk fever, according to this theory, was due to paralysis caused by a blood clot (thrombosis).

(8) *Fat embolism.* Penberthy (179) attributed the paralysis and coma to the formation of a fat embolism as the name of the theory infers.

(9) *Spinal traumatism.* Rogerson (202) attributed the paralytic symptoms to injuries of the spinal cord.

(10) *Aeremia.* Harms (99) attributed milk fever to the presence of too much air in the blood.

(11) *General infection.* Allemani (7), Harrison and Thomas (101), Potiez and Conceur (182) and van der Velde (252). This theory attributed the paralysis to the absorption of toxins of bacterial origin. No specific site of infection was indicated as in the following two theories.

(12) *Bacterial infection of uterine origin.* Rainaud (193), Pavesse (178), Wannovius (258), Lafosse (139), Stockfleth (238), Lanzilloti-Buonsanti (140), Zundel (278), Lyman (150), Schmidt-Mülheim (210), Friedberger and Fröhner (71), Pugh (192), Nochard (172), Guillebeau (94), Hess (115), Trinchera (250), Cozette (45), Lignieres (143) and Hartenstein (103). This theory cites the incriminating cause as being staphylococcic and streptococcic infection in the

uterus resulting in intoxication of the central nervous system, especially the medulla oblongata. This condition was different from puerperal septicemia in that in milk fever only an absorption of the toxins occurred, resulting in paralysis of the vaso-motor centers followed by congestion of the abdomen, uterus and udder with blood.

(13) *Infection of mammary origin.* Thomassen (247), Knusel (136), Hebbelynck (112), Parker (176), Delmer (49) and Schmidt (209). According to Schmidt, materials are present in the colostrum which are products of cellular disintegration due to toxins of unknown bacterial origin. This was the basis of the potassium iodide-injection treatment. Knusel believed the beneficial effects of oxygen inflation of the udder resulted from the destruction of anaerobic bacteria, which were responsible for the toxins which caused milk fever. Mastitis doubtless was troublesome in making a differential diagnosis when this theory was advanced.

(14) *Anaphylaxis.* Hutyra and Marek (125), and Van Goidsenhoven (253). The basis of this theory was the formation of antibodies during the preceding lactation due to the absorption of milk casein. The infrequent cases of milk fever at the first parturition were explained on the basis that sufficient milk is secreted to cause absorption of milk casein in high producers, as early as 2 mo. before parturition. This theory was not confirmed experimentally by injection of placental emulsion of milk or of colostrum. Alexandrescu and Cinca (3) could not produce milk fever symptoms in cows in which anaphylactic shock was induced with casein.

(15) *Mammary-neurasthenia.* Wooldridge (273) attributed milk fever to nervous prostration brought on by mammary congestion.

(16) *Avitaminosis.* Bayard (22) believed the milk fever syndrome was due to vitamin B_1 deficiency.

(17) *Anhydremia.* Shock resulting from anhydremia is the basis of the anhydremia theory of Harding (97, 98). The author admits that this does not explain the low blood calcium and phosphorus values. This theory was advanced in 1929 after the hypocalcemia theory. The work of Wilson and Hart (272) indicates that anhydremia is not a factor in milk fever because of the very slight differences in blood protein between normal and milk fever cows. The work of Hutyra and Marek (125) and Abderhalden (Hutyra *et al.*, 126) tended to disprove this theory, as it was shown that profuse bleeding did not produce milk fever symptoms. Law (141) reports that the size of the red blood cells is reduced in milk fever, due to anhydremia, excess salt and albumin.

(18) *Auto-intoxication.* Albrecht (2), Friend (72), Hodges (121), Fischer (61), D. Pugh (191), Allemani (8), Abadie (1), Schutt (213), Kaiser (132), Rainaud (193), Stohrer (240), Wieners (268), Nash (165), Thompson (248), Delmer (50), Menig (158) and Healy and Kastle (111). Auto-intoxication caused by toxins from the pregnant uterus, kidneys, udder epithelial lining, colostrum and distintegration products of milk proteins have all been advanced as causes of milk fever. Illnesses similar to milk fever, but which develop independently of parturition also were explained on this basis. Menig (158) claims

to have produced milk fever symptoms by tying off the renal arteries of cows. Healy and Kastle (111) attempted to show a similarity of milk fever to eclampsia in humans without success.

(19) *Defective oxidation in the tissues.* Fish (62, 63) cites the possibility of defective oxidation in the tissues, of unknown cause, as the basis of milk fever.

(20) *Excess oxytocic principle in blood after parturition.* This theory, advanced by Bell and Morris (23, 24) in 1934, was based on the finding that milk fever cows had more oxytocic principle in the blood than did control cows, but it was not confirmed experimentally.

(21) *Faulty protein metabolism.* In 1936, Scott (214) attributed milk fever to faulty protein metabolism resulting from the high protein content of cow's milk. No experimental evidence was presented in support of this theory.

(22) *Ovarian dysfunction.* Smith (230) believed milk fever is due to ovarian dysfunction; however, his experiments were uncontrolled and very fragmentary. This theory was reported in 1946. In 1947, Smith (231) reported further on this theory.

(23) *Hyperfunctioning of the anterior pituitary.* From 1937 to 1940, Seekles (215, 216, 217) published a series of papers in which he demonstrated the presence of ketogenic, glycogenolytic and hyperglycemic factors in the blood of milk fever cows; these factors resembled the corresponding anterior pituitary hormones. He also demonstrated antiketogenic and hypoglycemic factors comparable to antibodies of these pituitary hormones.

(24) *Disturbed cholesterin metabolism.* Moussu (164) (Hutyra *et al.*, 126) attributed milk fever to a decrease of blood cholesterin and acetone bodies due to beginning lactation. Hayden (106), however, showed that blood cholesterin does not increase following udder inflation and during recovery from milk fever.

(25) *Hyperadrenalinemia.* Zimmerman (Hutyra *et al.*, 126) was of the opinion that milk fever is caused by an excess of adrenalin in the blood at parturition due to an endocrine upset.

(26) *Magnesium narcosis.* Kloubok (134), Pribyl (190), Schulhof (212) and Seekles and Sjollema (218). The magnesium narcosis theory is based upon the similarity of symptoms between milk fever and those observed when $MgSO_4$ is injected into cows. Blood magnesium has been reported to increase in milk fever by many other investigators, including Allcroft and Green (6), Barker (16), Godden and Duckworth (81), Seekles *et al.* (221), Sjollema and Seekles (227, 228) and Hibbs *et al.* (120).

(27) *Alkalosis.* Craige *et al.* (46, 47, 48) concede that milk fever is a hypocalcemia but contend that this is brought on by alkalosis resulting from acid excretion into the colostrum, plus an alkaline diet. They recommend injecting chlorethamine (ethylenediamine dihydrochloride) along with calcium gluconate to relieve the alkalosis.

(28) *Acidosis and auto-asphyxiation.* Pierson (183) attributed milk fever to an acidosis that results in asphyxiation (lack of oxygen in the tissues).

(29) *Hypoglycemia.* Widmark (263), Widmark and Carlens (264, 265), Auger (12, 13, 14), Maguire (153) and Edwards (57). This theory will be dis-

cussed in detail later. In the course of experiments designed to prove or disprove this theory much knowledge has been added to the nature of milk fever.

(30) *Parathyroid deficiency* (*Hypocalcemia*). Dryerre and Greig (54, 55), Greig (89, 90, 91), Barker (16), Fish (63, 64, 65, 66, 67), Godden and Duckworth (81), Allcroft and Green (6), Little and Wright (147, 148), Little (144), Little and Mattick (146), Seekles and Sjollema (218), Seekles *et al.* (221), Sjollema (224, 225), Sjollema and Seekles (227), Wilson and Hart (272), Petersen *et al.* (180), Hibbs *et al.* (117, 119, 120), Smith *et al.* (232, 233), Niedermier *et al.* (169, 170) and Blosser and Smith (29). This theory also will be discussed at length as it is the basis for much of our present understanding of the nature of milk fever.

Several reviews of the nature of milk fever appear in the literature. Thomassen (247), Dryerre and Greig (54), Little and Wright (147), Hutyra and Marek (125), Greig (89), Sjollema (226), Udall (251), Giltner (77) and Isherwood (127) are a few. The symptoms and treatments are described adequately in nearly all textbooks on diseases of cattle.

The Schmidt (Udder Inflation) Treatment

The first epoch in milk fever history occurred in the year 1897. In that year, a veterinarian by the name of Jurgens J. Schmidt (209) of Kolding, Denmark, brought forth his theory that the cause of milk fever was a virus infection of the udder. This theory resulted ultimately in the udder inflation treatment and immediately reduced the mortality hazard of milk fever from 60 to 70 per cent to about 15 per cent.

Schmidt's theory was based on a mistaken observation. In subjecting the colostrum of affected cows to microscopic observation, he noticed what he believed to be evidence of cellular disintegration and concluded that some ferment or toxin within the udder was responsible for the decomposition of the epithelial lining of the udder. He believed this was caused by a virus infection. What Schmidt probably saw were normal constituents of colostrum, colostrum bodies, or corpuscles of Donne (mononeuclear cells filled with fat droplets), which he would have discovered had he controlled his observations and examined the colostrum of normal cows as well.

In order to destroy the infection, he selected KI (1 per cent solution) and injected it into the udders of cows with milk fever. This treatment was remarkably successful and, when adopted, reduced the mortality of the disease to 15 per cent.

Other veterinarians found that different percentages of KI could be used, as well as 1 per cent, and that different amounts of the solution were equally effective in curing milk fever. Water alone likewise was effective.

Anderson and Evers of Skanderborg are said to have been the first to practice udder inflation with air alone in 1901. They found that oxygen was no more effective than air. With this discovery the mortality was reduced to about 1 per cent. A thorough discussion of udder inflation appears in Hutyra and Marek (125). Zehl (276) is credited with the development of the double air catheter

used in air inflation of the udder. Thus, through an erroneous observation and a false deduction, an effective cure of milk fever was discovered. However, the basic cause of milk fever was yet unknown; in fact, as Greig (89) stated, "the very specificity of the cure rendered the nature of the malady all the more obscure; yet the problem was the more attractive by reason of its apparent simplicity."

The Schmidt treatment and its modifications introduced a new hazard, that of mastitis, unless practiced with extreme aseptic precautions. This is emphasized by Jensen (129).

Except for minor variations in the Schmidt treatment and improvements in the apparatus for udder inflation, very little was done experimentally which expanded the knowledge of the nature of milk fever until about 1925. About this time two new theories were advanced, both of which have been subjected to extensive scientific investigation, namely, the Hypoglycemia and the Parathyroid deficiency (Hypocalcemia) theories. Although the former theory since has been refuted, the experiments carried out in connection with these two theories are largely responsible for our present understanding of the nature of milk fever.

The Hypoglycemia Theory

Nochard (171) in 1885 first noticed sugar in the urine of milk fever cows. He did not distinguish between glucose and lactose.

According to Neefs (167), this concept of milk fever had its origin in 1923 when a Canadian veterinarian, whose name is not recorded, was impressed by the similarity of symptoms between insulin shock and those of milk fever. It is said that he effected a cure in a milk fever cow by the intravenous injection of glucose. This never was recorded in the literature.

Widmark and Carlens (264, 265, 266, 267) and Widmark (263) have published a series of papers in support of the hypoglycemia theory. They attributed the disease to glucose deficiency brought on by the intensity of mammary secretion. Widmark suggests that it is a reaction to advanced breeding. Maguire (153) reported the successful use of intravenous injections of glucose in milk fever. He explained the action of glucose in milk fever thus: Insulin is a hydrator (causes protein particles in blood to enlarge and precipitate in the cerebral capillaries). Glucose, a dehydrator, causes the opposite effect and alleviates the symptoms produced by excessive insulin production in milk fever. Later in the same year, Maguire (154) abandoned this concept and agreed with Auger (12) and McLeod (152) that milk fever was caused by hypoglycemia resulting from removal of glucose by the mammary gland. Edwards (57) cited hypoglycemia after parturition in dogs in support of the hypoglycemia theory of milk fever.

Support was given by Hoyois (123) and Bru (34) to the view that milk fever is dependent upon an abundant milk secretion; they reported that repeated milking after parturition favored the appearance of milk fever. Hoyois (123) stated that milk fever did not occur if the cow had an attack of mastitis immediately after parturition, as this stops milk secretion.

The experiments of Porcher (184, 185, 186) and Kaufmann and Magne (133) have shown that lactose in milk originates from the blood carbohydrates and that lactose is readily absorbed back into the blood stream and is excreted in the urine. This was offered in explanation of the lactosemia observed in milk fever. Porcher and Panisset (187) state that colostrum is only a milk modified by retention. Porcher and Tapernoux (188) showed that lactose injected into the udder of a dry goat was largely absorbed into the blood stream.

Maguire (154) argues that intensive feeding will not cause milk fever and cites the practice of English breeders of feeding a high carbohydrate ration ("steaming") before parturition. This practice, while it increases milk secretion, also builds up the carbohydrate reserves and is said to prevent milk fever. Accordingly, mammary inflation was supposed to effect a cure by raising the blood sugar, as the experiments showed.

After the hypoglycemia theory had been advanced by these authors, papers by Hayden and Sholl (104), Hayden (105, 106), Fish (62, 63), Little and Keith (145) and Moussu and Moussu (163) showed that hyperglycemia was found in milk fever, rather than hypoglycemia. In 1926, Greig (85) criticized the hypoglycemia theory on the basis that the experimental evidence showed a hyperglycemia rather than a hypoglycemia. Auger (13, 14) replied that the high blood sugar values are due to a mixture of glucose, which is available to the tissues, and lactose, which is reabsorbed from the mammary gland and which is not available to the tissues. Thus, although an increase occurred in total sugar, the actual available sugar (glucose) is deficient in milk fever.

In 1926, no method was available for differentiating between the two sugars in the blood. It was reasoned by Greig (89) that if glucose was in excess, some would be found in the urine. This he was able to demonstrate in four out of 14 samples of urine from milk-fever cows. Amadon (9) reported that there is not sufficient hypoglycemia during milk fever to cause coma. This matter was conclusively cleared up by Hayden (105) when he was able to show a relative hyperglycemia in the blood of milk-fever cows using the Folin-Svedburg (68) method for differentiating between glucose and lactose in the blood and urine. Hayden (105, 109) showed, in addition to hyperglycemia, that lactose occurs only occasionally before mammary inflation but that the increase in total sugar of the blood after mammary inflation is due to reabsorbed lactose which is unavailable to the tissues and is excreted promptly.

These experiments conclusively showed that milk fever is not due to hypoglycemia and indirectly gave support to the hypocalcemia theory of Dryerre and Greig (54), which was advanced at approximately the same time.

Petersen *et al.* (180) later were unable to demonstrate milk fever symptoms when the blood sugar of cows was lowered to 17 mg. per 100 ml. by the injection of insulin.

Schlotthauer (208) in connection with a review of milk fever theories, especially the hypoglycemia theory, presented evidence that a hyperglycemia, rather than a hypoglycemia, is present in milk fever.

The Parathyroid Deficiency (Hypocalcemia) Theory

The parathyroid deficiency (hypocalcemia) theory without supporting experimental evidence, was first published early in 1925 by Dryerre and Greig (54). According to Greig (89), he and Dryerre became interested in the milk fever problem in 1924 and resolved to undertake the investigation of the problem. Their approach was that of submitting the whole problem to a process of reasoning, after first collecting all the available evidence bearing on the occurrence and clinical manifestations of the disease. The results of this process of reasoning were presented (54) in the form of a working hypothesis, without experimental evidence to support it. The following are the main points considered in formulating the parathyroid deficiency (hypocalcemia) theory, as described by Greig (89):

"Commencing with the fact that specific cure resulted, no matter whether antiseptic fluids, sterile water, oxygen or air were injected into the udder, it seemed obvious that the effect, whatever it might be, depended upon the mechanical distention of the mammae.

"We then premised that simple distention of the mammae must act either:

1) by eliciting some endocrine disturbance, and/or

2) by mechanically retarding or arresting milk secretion, and so preventing the loss in the milk of some substance vital to the organism.

"That the disease was in some way closely associated with milk secretion was suggested by the facts that:

1) Its appearance as a clinical entity was coincident with the commencement of the development of the modern heavy milking strains.

2) It was much more prevalent in dairy breeds as distinct from beef breeds.

3) It very commonly attacked those individuals which specially possessed deep milking qualities.

4) The period of greatest susceptibility in the milking life of an individual cow corresponded to the period of greatest milk secretion. Primiparae were very rarely affected.

5) The rapid emptying of the udder by hand might precipitate the onset, while the practice of repeatedly removing small quantities of milk, or, alternatively, of permitting the calf to suck the cow for the first few days after calving, was recognized as a valuable preventive procedure.

"The milk cow has been bred to produce an enormous quantity of milk; indeed, her milk secretion may now be regarded as almost pathological.

"The colostrum of the cow is rich in calcium, and it was considered likely that the onset of a profuse lactation might occasion a rapid reduction in the concentration of the blood calcium. This idea seemed to be supported by our further observations that the spastic seizures which often characterize the early stages of milk fever were tetanic in character.

"We believed that the mere mechanical withdrawal of calcium from the blood as a result of the onset of a profuse secretion of milk could not in itself be regarded as the cause of milk fever, because, if this were so, every heavy milking cow would be subject to the disease.

"For that reason we postulated that some other factor, therefore, must act as a predisposing cause, and we suggested that such might be found in parathyroid dysfunction.

"The following, then, were the essential points in our hypothesis:

1) The nature of milk fever may be understood as a parathyroid deficiency, resulting in the accumulation of toxic substances such as guanidine, and a fall in blood calcium, the fall in calcium being further accentuated by lactation.

2) The curative effect of mammary inflation is due to (a) the stimulation of adrenal secretion and the consequent oxidation of toxins, and/or (b) the retardation of the formation of milk and the consequent prevention of further free exchange of calcium from the blood to the milk.

3) The preventive value of a restricted withdrawal of milk from the udder after calving is due to this procedure conserving the concentration of calcium in the blood."

Evidence Supporting the Hypocalcemia Theory

In May, 1925, Little and Wright (147) first reported that blood serum calcium is low in milk fever and that the severity of the symptoms was in accord with the degree of blood calcium diminution. In mild cases a 20 to 30 per cent reduction in blood calcium was found, whereas in severe cases up to 60 per cent reduction was observed.

The view originally held by Dryerre and Greig that udder inflation stimulated secretion of adrenalin has since been abandoned in the light of the experiments of Auger (13), who was unable to demonstrate any increase in blood pressure after udder inflation.

More recent work by Hayden (106) indicates that guanidine accumulation is not an important factor in the causation of milk fever, as originally suggested by Dryerre and Greig (54). Fish (62) cited the work of Watanabe (260) as evidence of the possible association of guanidine to metabolic changes in milk fever. Hypocholesterolemia, according to Hayden (106), is not a factor in the causation of milk fever, as the values were lower after inflation than before. There was, however, a decrease in the blood cholesterol of parturient cows.

Numerous reports, subsequent to the originals, have been made by Dryerre and Greig, Little and Wright and others which directly or indirectly give support to the essential basis of this theory. Little and Wright (148) point out that 0.5 gal. of colostrum contains as much calcium as is present in the blood at any one time. They attribute much importance to the drain on blood calcium by the secretion of colostrum in the precipitation of the milk fever attack. Dryerre and Greig (55) also reported low blood calcium values in milk fever as further evidence in support of their theory.

In 82 cases of milk fever, Greig (88) reported minimum, maximum and average serum calcium values of 3.00, 7.76 and 5.13 mg., respectively, per 100 ml. No hypocalcemia was found in a study of 81 cases of diseased animals which did not have milk fever (88).

In 15 cases of milk fever successfully treated by udder inflation, Greig (88) demonstrated that the blood calcium rose rapidly to normal and continued to above normal levels after recovery, which resulted when a concentration of about 7 mg. per 100 ml. was reached. It was suggested that inflation of the udder not only stops the secretion of calcium into the milk but may force calcium from the milk back into the blood stream.

Fish (65) reported average milk fever blood plasma values of 3.31 mg. per 100 ml. for calcium and 2.39 mg. per 100 ml. for phosphorus. Phosphorus reached normal after inflation of the udder and rose above normal values in 6 to 8 hr., while calcium was still below normal after 24 to 36 hr.

Niedermier and Smith (170) recently reported data on the blood levels of calcium, phosphorus and magnesium during the recovery period for seven cases of milk fever treated by udder inflation. They pointed out that different cows recovered at different blood calcium levels and suggest that the relative levels of calcium, phosphorus and magnesium may be more important in the symptomatology of milk fever than the level of any one constituent.

Greig (86) showed that a blood picture similar to that of milk fever occurs in "lambing sickness" in ewes and that both udder inflation and calcium gluconate injection were effective as cures.

In 1935, Dryerre and Greig (56) recommended the subcutaneous injection of calcium boro-gluconate as a treatment of milk fever. The nature of this compound is discussed. This treatment reportedly cut down the severity of the heart reactions and decreased the number of relapses due to its slower absorption. The injection of 1 to 2 oz. of calcium boro-gluconate immediately after calving and repeated after 20 hr. was recommended for the prevention of milk fever.

In 1933, Mattick and Little (155) reported on a study of the calcium and phosphorus content of cow's blood. Their findings can be summarized as follows: (1) The calcium and phosphorus content of heifers' blood decreased at parturition. This decrease could not be altered by ultra violet irradiation (one cow). Erf (58), however, reports that blood calcium in cows was elevated by ultra violet irradiation, especially when the skin was oiled with cod liver oil. (2) Parathyroid injections were of doubtful value in preventing or curing milk fever (450 Hansen units as "Paroidin" daily for 4 days before, on the calving date and one day after parturition). (3) Drenching with calcium lactate and $CaCl_2$ had no beneficial effect on blood calcium; however, $CaCO_3$ plus cod liver oil may have been beneficial in one case. (4) Diffusible calcium was never above 3 mg. per 100 ml. in eight cases of milk fever, whereas total calcium was only once above 6 mg. per 100 ml. (5) Slow intravenous injections of $CaCl_2$ solution were specific in curing all cases of milk fever, as had been previously reported by Sjollema (224). (6) Excess amounts of phosphorus in the pastures, fish meal or insufficient lime in feedstuffs seemed to favor the development of milk fever.

Little and Mattick (146) were unable to prevent the decrease in blood calcium at parturition by feeding cod liver oil, although a slight beneficial effect was noticed. A greater percentage drop in diffusible calcium was observed at parturition than in total calcium. Diffusible phosphorus was shown to decrease more than total phosphorus. Phosphorus values returned more rapidly to normal at parturition than did calcium values and the phosphorus values seemed to be higher at parturition in the group fed cod liver oil than in the control group. Methods for both diffusible phosphorus and calcium are described.

Stimulated by the work of Dryerre and Greig and Little and Wright, numerous research workers in all parts of the world reported experiments dealing with various phases of the milk fever problem.

Sjollema (224, 225), of the University of Utrecht, reported low values for both serum calcium and phosphorus in 40 milk fever cases and recommended 300 to 400 ml. of 10 per cent $CaCl_2$ as a cure. He stressed the importance of upset electrolyte balance in the etiology of milk fever as a result of determining the calcium, magnesium, potassium, chloride, phosphorus, pH and alkaline reserve on blood serum and of total sugar, glucose, urea and total acetone in whole blood.

Fish (63, 64, 65, 66, 67) presented evidence against the hypoglycemia theory and in support of the hypocalcemia theory. He pointed to the disturbed nitrogen metabolism and hyperglycemia of milk fever cows as an indication of defec-

tive oxidation in the body and the presence of a series of phenomena in milk fever. Decreased calcium and increased guanidine indicated that the parathyroids were involved. He brought attention to the ratio of calcium to phosphorus in milk fever (64). The Ca : P ratio in the blood of milk fever cows is 1.9; in normal cows the Ca : P ratio is 2.31. Ca × P in milk fever cows is 8.18 and in normal cows is 50.08. He suggested that hyperglycemia seen in milk fever may be due to disorganization of the hexose phosphate constituent in muscle due to the low blood phosphorus, but that it is of no particular significance so far as the etiology of milk fever is concerned.

In discussing Harding's theory of anhydremia, Fish (66) indicated a 14 per cent increase in red blood cells and a 7 per cent decrease in serum protein in milk-fever cows. Fish (67) and Gould (83) stressed the importance of diet in preventing milk fever. Phosphorus was believed to be just as important as calcium in the diet. Calcium glycerophosphate with glucose was recommended for intravenous treatment. Appleby (10) recently has recommended the use of calcium boro-gluconate-saccharate as a treatment for milk fever.

A comprehensive review of the knowledge of milk fever in 1932 is given by Sjollema (226). The disease is discussed from the standpoint of occurrence, metabolism, etiology and therapy.

From 1930 to 1932 Sjollema *et al.* (227, 228, 229) and Seekles *et al.* (218, 219, 220, 221) published a series of papers which added materially to the knowledge of the etiology of milk fever.

Sjollema (227, 228) drew comparisons between the blood picture of normal cows and those with milk fever and grass tetany, as follows:

	Ca ion (*mg. %*)	Inorg. P (*mg. %*)	Mg (*mg. %*)	Total Ca (*mg. %*)
Milk fever	0.44	2.16	2.19	4.35
Grass tetany	1.18	4.33	0.46	6.65
Normal cattle	1.65	4.57	1.66	9.35

Ca : Mg ratio equals 2 in milk fever and is 14.6 in grass tetany. The diffusible calcium level of the blood paralleled the severity of the symptoms more closely than did total serum calcium. This also was reported by Seekles *et al.* (220).

Carlstrom and Ecklund (Hutyra *et al.*, 126) injected sodium oxalate into cows, causing hypocalcemia and symptoms of milk fever.

Sjollema *et al.* (219) also injected sodium oxalate into cattle and observed the symptoms. Serum calcium was greatly reduced and death with clonic convulsions occurred when levels lower than 4.0 mg. per 100 ml. were reached. Sodium citrate did not lower the total serum calcium. He concluded that milk fever is not simply the result of lowered serum calcium but that this is only part of a more general disturbance of metabolism. Similar experiments using sodium citrate were carried out by Petersen *et al.* (180) with the same results and conclusions.

Blosser and Smith (29) in a recent publication have shown a significant cor-

relation between blood serum citric acid and calcium during the period of parturition. A marked drop in blood citric acid occurred at parturition in both normal and milk fever cows.

Sjollema, *et al.* (218), in a series of papers on the mode of action of calcium, noted that after injection of sodium oxalate, serum calcium was at its lowest within 10 min. The reduction was relatively less for the ultrafilterable than for the "bound" fraction. A residue of 3 to 4 mg. per 100 ml. exists which is not precipitated by large excesses of oxalate. Calves were less sensitive to oxalate than older cattle. When serum calcium is lowest, heart symptoms may occur. Ataxia, paralysis and tremor occur after the lowest point is passed when serum calcium is again rising.

Magnesium sulfate was injected into calves to produce magnesium narcosis which, according to Kloubok (134), Pribyl (190) and Schulhof (212), is the cause of milk fever. The Ca : Mg ratio in the injected calves was similar to that found in milk fever, and $CaCl_2$ injections were curative in both cases. Hayden (107) claims the slight increase in serum magnesium in milk fever is of no significance, based on the normal values of Eveleth (59). Meltzer and Auer (157) have demonstrated an antagonism between serum calcium and magnesium. In studying the effects on the heart of injected $CaCl_2$ and $MgCl_2$ in milk-fever and grass-tetany cows, they showed that the effect of each injected separately was the same, resulting in increased rate and disturbed rhythm. When injected as a mixture, no toxic symptoms resulted. In 30 cases of milk fever injected with a mixture of $CaCl_2$ and $MgCl_2$, some of which had extremely low ionized calcium and were likely to develop heart block, no bad effects were observed. This work later was confirmed by the same authors (229).

Waife (256) in studying "Partial heart block in hyperparathyroidism" describes incomplete heart block during hypercalcemia which may not disappear completely when serum calcium returns to normal or falls below normal. The electrocardiogram showed long Q.-T. intervals when serum calcium was below 8 mg. per 100 ml. Spörri and Raggenbass (236) also have studied the effect of calcium and air insufflation therapy of milk fever on the electrocardiogram. They found that after calcium injections, the electrocardiogram returned to normal. Hypocalcemia had a marked effect on the heart musculature.

In a study of the effect of blood changes on the tone of the autonomic nervous system during pregnancy and parturition in normal cattle, Seekles and Sjollema (221) reported that serum calcium and phosphorus decreased about 4 days before parturition, reaching a low point just before or shortly after parturition. Serum magnesium was in inverse relation to calcium and phosphorus. Potassium reached a minimum several days postpartum. These marked fluctuations are attributed to "lability of the regulatory mechanisms." Blood sugar increased in seven cases at parturition. No change in "rest nitrogen" was observed. The vagus tone of the heart increased as pregnancy progressed, due to the rise in the K : Ca ratio. An atypical case of milk fever was believed to have been cured by the injection of parathyroid extract. The total calcium was lower after recovery but the ionized calcium was doubled. Seekles *et al.* (220) reported that $CaCl_2$

will raise the total calcium in the blood and that parathyroid injections raise the ionized calcium. Both were alleged to cure the symptoms.

Palmer *et al.* (174, 175) had previously reported a decrease in both calcium and phosphorus in the blood of normal cattle at parturition, as had Godden and Allcroft (80). Phosphorus apparently is capable of wide variations without affecting the health of the cow. Normal values and variations in milk fever for serum calcium, phosphorus and magnesium also were reported by Allcroft and Green (6). Allcroft and Godden (5) reported increases in magnesium at parturition or 24 hr. thereafter in normal cattle. Godden and Duckworth (81) reported values for serum magnesium, calcium and calcium partition in the blood of cows at parturition and in milk fever. A steep fall in total serum calcium preceded the acute symptoms of milk fever before and at calving. The symptoms arise when there is a simultaneous fall in both adsorbable calcium complexes and the non-adsorbable calcium ("protein-bound" calcium plus calcium ion). The fall in adsorbable calcium complexes accounts for the major part of the fall in total serum calcium in milk fever. Serum magnesium and calcium rise together during the recovery stage of milk fever.

As a possible explanation of the low serum phosphorus values in milk fever, these authors suggested that this would be expected when a fall in the ultrafilterable calcium complex occurs. Benjamin and Hess (25) showed that, in the low-phosphorus type of rickets, the adsorbable calcium complexes were below normal and that this was coincident with low serum inorganic phosphorus. Benjamin and Hess (25) also showed that ultrafilterable calcium complex contained calcium, phosphate and bicarbonate ions. Thus, any decrease in the amount of ultrafilterable calcium complex would result in a corresponding decrease in the inorganic phosphorus, unless more phosphorus were secreted into the blood stream to make good this deficit. Therefore, instead of the normal inverse relationship between calcium and phosphorus in the blood, both calcium and phosphorus fall together in milk fever, caused by the tremendous reduction in the $(Ca)_x(Po_4)_y(HCO_3)_z$ complex resulting from colostrum formation. The failure to mobilize calcium in milk fever, whether directly or indirectly dependent on the parathyroids, or not, thus would account for the low phosphorus in milk fever.

Frei and Demmel (70) reported very little variation in serum composition in lactating and pregnant cows. The changes in milk fever were attributed to disturbances in the endocrine and vegetative nervous system associated with parturition, rather than the onset of milk secretion. These authors linked the vegetative nervous system, metabolic centers in the medulla, endocrine and blood ionic equilibrium, and considered a disturbance at any one point to affect the whole chain.

Robinson and Huffman (201) reported that the blood bicarbonates are lowered after parturition.

Hayden (107) reported low lipoid, total acid-soluble and total phosphorus in milk fever. In later papers, Hayden (108) and Sampson and Hayden (205) showed that the CO_2 capacity of the blood is lowered in milk fever and acetonemia and that blood ketones are increased.

Hart *et al.* (102) reported that HCl fed to cows increased the urinary calcium excretion and also the absorption of calcium.

Wilson and Hart (272), in a detailed study of blood constituents, presented evidence that anhydremia is not an important factor in milk fever due to the slight lowering of protein values in milk fever as compared to normal calvings. A greater decrease in serum calcium and phosphorus occurred at parturition in older cattle than in first-calf heifers. Blood phosphorus and calcium were found to decrease sometime during the first 3 days postpartum. Additional evidence was presented showing that serum calcium deficiency is the essential factor in milk fever.

In a study of the plasma phosphatase, these same authors found that there is a decrease from 3 wk. pre-freshening to near the time of calving when it tends to increase, falling again during the 3 wk. postpartum. Milk phosphatase was higher than plasma phosphatase, being especially high at the end of lactation, as compared with beginning lactation in heavily producing cows.

Allcroft and Folley (4) indicated that serum phosphatase varies widely among individuals but is rather constant in the same individual over long periods. Pregnancy raises serum phosphatase activity but there was no correlation with stage of lactation. There was no correlation between milking capacity and phosphatase activity.

Predisposing Factors

Ever since milk fever first was mentioned in the literature, numerous conditions have been associated as predisposing factors. It immediately was recognized that age was one of these. First-calf heifers were seldom, if ever, known to have milk fever and it was recognized that from 5 to 10 yr. of age, the period of highest production, are the years in which milk fever is most likely to occur. Metzger and Morrison (159) and Henderson (113) presented data confirming this observation.

Milk fever usually is thought to be associated with "deep milking qualities" or heavy producing cows. However, this is not a hard and fast rule, as numerous cows which were not outstanding producers have been known to have milk fever.

Hibbs (117) has presented evidence that milk-fever cows produce no more colostrum than cows that freshen normally and that the ash and calcium content of the colostrum of milk-fever cows is no higher than that of cows freshening normally.

Heavy feeding during the dry period has been cited as a factor leading to milk fever. A 50 per cent decrease in occurrence was noted during World War I in Europe, according to Gruter (89), when feed was scarce.

Scottish farmers are said to feed straw and turnips during late pregnancy as a preventive measure. However, Maguire (153) stated that the system of "steaming," or heavy feeding of grain high in carbohydrate and protein, used by English farmers in late pregnancy is said to decrease milk fever incidence and raise milk production. This, therefore, is a controversial question.

Confinement sometimes is associated with milk fever, although there is little basis for this idea. Albrecht (2), in 1904, observed that milk fever disappeared from a herd when cows were allowed to calve out in the open instead of in closed stalls.

Diets high in phosphorus and/or deficient in calcium have been cited as the cause of milk fever by Gould (83), Fish (64), Little *et al.* (144, 155) and Götze (82), to name a few.

Götze (82) stated that gestation and lactation test, to the limit of endurance, the visceral nervous system if important mineral constituents are lacking or are in excess. He was of the opinion that success in research on milk fever is not to be found in research on therapeutics but in appropriate nutrition which will keep the visceral nervous system balanced. He stressed the importance of mineral balance of the soil on which roughage is grown and suggested that the composition of roughage and concentrates should be known and balanced with supplements.

Greig (91), in the discussion of the paper by Götze, pointed out that milk fever is an acute hypocalcemia brought on by sudden onset of lactation (easy parturition, no mastitis, etc.). The parathyroids being quiescent, the tissue calcium cannot be mobilized. He stated that colostrum contains more calcium than the blood at any one time. Therefore, he believed that balanced intake is not of major importance in the etiology of milk fever.

While diet may be a factor, the present understanding of the etiology of milk fever does not favor this concept, especially in view of the rapidity of the changes in blood calcium and phosphorus both in the onset and during the recovery period of milk fever.

Krøgoe and Petersen, according to Hutyra and Marek (126), claimed that more cases occur when the barometer is falling than when it is high. This was denied by Stenius (Hutyra *et al.*, 126) who observed 54 per cent when the barometer was falling, 9 per cent when stationary, and 37 per cent when rising. Stenstrup (Hutyra *et al.*, 126) reported only 15 out of 94 cases of milk fever occurred during or following a fall in atmospheric pressure. Heately and Dryerre (Hutyra *et al.*, 126) showed no correlation with climatic conditions in prolonged observations. Hallgren (96) and Morin (162) also denied the claim that milk fever is more likely to occur during a falling barometer. Likewise, Hibbs (117) has presented evidence that there is no correlation between barometric pressure and the onset of milk fever. Morin (162) stated that milk fever rarely occurs in premature calvings but frequently in overtime cases and when a large calf is born.

Cows that have one attack are likely to repeat at subsequent parturitions. This indicates impairment of resistance, according to Hutyra and Marek (126), rather than that the cow is rendered more susceptible by the first attack.

Considerable data indicates a breed difference in susceptibility to milk fever. Henderson (113) and Metzger and Morrison (159) indicated that cows of the Jersey breed are many times as likely to develop milk fever as cows of the same age group in other breeds. Hibbs *et al.* (119) confirmed this observation. How-

ever, Hibbs *et al.* (119) were unable to show a seasonal variation in the incidence of milk fever, as was shown by Henderson (113) and Metzger and Morrison (159), who reported a higher milk fever incidence in the winter months than in the summer months. Henderson (113) reported 4.07 per cent of susceptible parturitions in the months of May to September and 13.35 per cent in the months of October to April. Evidence presented by Smith and Blosser (232) also indicates that there is no seasonal influence on milk fever incidence.

In weighing all the experimental evidence that has been reported on the various phases of the milk fever problem, the theory of Dryerre and Greig seems to come the nearest of all theories to explaining the cause of the disease. However, numerous questions are as yet unanswered. One of these is whether or not deficiencies in the feed result in the upset mineral metabolism seen in milk fever. As Sjollema (226) points out, mineral deficiencies in the feed are the cause of such disorders as aphosphorosis, rickets, sterility and border-line conditions which only develop acutely when some other agent is operative.

Milk fever symptoms do not develop in conditions such as nephritis or during recovery from parathyroidectomy in dogs, although the serum calcium level is comparable to that seen in milk fever. The difference in symptoms between milk fever and nephritis possibly is explained on the basis of the ionized calcium level, according to Sjollema.

Furthermore, milk-fever symptoms are not seen in aphosphorosis of cattle in South Africa, although the blood levels are comparable insofar as phosphorus is concerned. However, the possible effects of diet, repeated lactations and maturity of the animal on the supply of readily available stores of calcium and phosphorus in the bones must not be overlooked in this connection.

The fact that the onset and recovery from milk fever is so sudden, regardless of treatment (calcium injection or udder inflation), is further indication that a dietary deficiency may not be a primary etiological factor, except as it may influence the supply of readily available calcium and phosphorus stored in the tissues.

It seems that the drain on the blood calcium for the production of colostrum is not the primary cause of milk fever since, as shown by Hibbs (117), in normal parturitions an equal drain on blood calcium and phosphorus for colostrum production is experienced which results in but a slight decrease in the blood levels. It is more likely that the cause is the inability of the regulatory system to meet this sudden demand through mobilization, as suggested by Greig. The cause of the failure of the blood calcium regulatory mechanism to meet the demand is yet to be discovered. It is reasonable to believe, however, that colostrum production does act as a "precipitant" in the chain of events leading to the onset of milk fever.

Based on differences in calcium values between the jugular and mammary veins, Hallgren (96) attributed the lowering of serum calcium in milk fever to its excretion in the colostrum.

The recent work of Smith *et al.* (232, 233) is of great interest in this connection. They have shown that no decrease in milk fever incidence resulted from

prepartum milking, nor did any increase in incidence result from complete milking as compared to partial milking after parturition. Niedermier *et al.* (169) have shown further that the blood serum calcium and fat decrease less at parturition in mastectomized cows than in cows whose udders are intact. Serum magnesium did not increase at parturition in the mastectomized cows as it does in normal cows. Serum phosphorus levels showed a drop in both mastectomized and normal cows.

The answer to the question of how equilibrium is restored so rapidly following treatment is not apparent from experimental evidence presented to date.

Blood Magnesium Level as Related to Milk-fever Symptoms

The central nervous system apparently is involved in the appearance and disappearance of the symptoms of milk fever. Seekles and Sjollema (218), as previously mentioned, have shown that the comatose condition produced in calves after magnesium injection is cured immediately by calcium injection. In experiments with rabbits this effect took place only if the corpus striatum was intact (Yamawaki, 274).

Barker (16) recognized three types of hypocalcemia, depending upon the level of serum magnesium. The symptoms seen varied from extreme nervousness and tetany when magnesium was low to a comatose condition when magnesium was high. He recommended a 25 per cent $MgSO_4$ solution be given along with calcium gluconate as a treatment for milk fever.

Neuwirth and Wallace (168), working with dogs, showed that a profound coma resulted when the serum magnesium was raised to 18 to 21 mg. per 100 ml. by injecting $MgSO_4$. Greville and Lehman (93) have shown an antagonism between magnesium and calcium in muscle. Meltzer and Auer (157) showed that dogs and monkeys could be brought out of magnesium narcosis by calcium injections.

Sjollema *et al.* (218) found that calves injected with $MgSO_4$ so as to produce a comatose condition were cured by the intravenous injection of $CaCl_2$.

Moore and Wingo (160), in investigating the blood level of magnesium ion in relation to its lethal, anesthetic, analgesic and antitetanic effects, found that in cats under nembutal anesthesia the fatal blood level of magnesium was 24.7 mg. per 100 ml. In dogs under similar conditions, the lethal level was 24 to 32 mg. per 100 ml. The fatal blood level of magnesium increased somewhat when the degree of anesthesia was decreased. When calcium was injected concurrently with magnesium, the fatal level of magnesium increased to 65.8 mg. per 100 ml. Low doses were found to offset tetany due to low calcium.

An interesting sidelight is the report of Suomalainen (241) who reports that during hibernation in the hedgehog, the serum magnesium increases from a normal of 3 mg. per 100 ml. to 6 mg. per 100 ml., while the serum calcium remains constant at from 9.8 to 10.6 mg. per 100 ml. Thus, the Ca : Mg ratio during hibernation is not far from that seen in milk fever in cows.

It was apparent from the results of Hibbs *et al.* (117, 120) that the anesthetic effect of magnesium is due to the ratio of calcium to magnesium, regardless of

whether the serum calcium comes down to meet the magnesium, as in milk fever or when sodium oxalate is injected, or the serum magnesium goes up to meet the serum calcium, as when magnesium salts are injected.

The increase of serum magnesium preceding milk fever is not readily explained. Possibly it is due to a compensatory measure elicited by the fall in serum calcium, or it may be a protective antitetanic phenomenon. However, it seems reasonable to conclude that the relatively high serum magnesium accounts for the lack of tetanic symptoms in typical milk fever and the comatose condition which usually is seen in spite of the low blood calcium level.

Parathyroid—Vitamin D—Blood Calcium Relationships

The role of the parathyroids presents a challenging phase for future research in milk fever. Morgan *et al.* (161) have shown that dogs on a vitamin D-deficient diet showed a smaller response to parathyroid injections in serum calcium than normal dogs and that on low-calcium diets an increase in serum calcium resulted only after the first injection of parathyroid extract.

Campbell and Turner (35) reviewed the literature pertaining to the relation of parathyroid activity to calcium metabolism. Collip (41) was one of the first to demonstrate the function of the parathyroid glands in the regulation of blood calcium.

Seekles *et al.* (220) claim that milk fever was cured in a few cows by parathyroid extract injections.

Jaffe *et al.* (128) suggest that, in hyperparathyroidism, calcium is rapidly resorbed from the sites of rapid bone growth. Thus, young rapidly-growing animals respond to injections of parathyroid hormone more readily than do older animals. This may be the explanation of, or at least a factor in, the common observation that cows usually do not develop milk fever until after the second parturition or after the period of rapid bone growth. Bodansky and Jaffe (30) state that the hypocalcemia following hypercalcemia induced by parathormone injection is due to calcium redeposition in the bones. Holtz *et al.* (122) confirm this observation.

Gerschman (75) and Patt and Luckhardt (177) report a reciprocal relationship between parathyroid activity and the blood serum level of calcium. Stoerk and Carnes (239) have found a linear inverse relationship between parathyroid volume and serum calcium levels between 7.3 and 11.9 mg. per 100 ml. in the rat.

Taylor *et al.* (242, 243) show that the effects of excessive doses of irradiated ergosterol upon calcium and phosphorus metabolism of the dog run closely parallel with those resulting from parathyroid overdosage. Species showing a high resistance to the toxic action of irradiated ergosterol also are correspondingly tolerant to the action of parathormone. These authors favor the hypothesis that vitamin D increases serum calcium primarily by its effect on parathyroid tissue.

Taylor *et al.* (244) have shown further that dogs made tolerant to parathyroid were resistant to large doses of irradiated ergosterol (400,000 I.U./kg. for three doses).

A limited amount of work with cows done by Hibbs *et al.*, some of which has

been reported (118), showed that a response of 1.5 to 2.0 mg. per 100 ml. in serum calcium and phosphorus resulted 15 to 20 hr. after injecting 2,000 to 3,000 units of "Paroidin" subcutaneously. A transitory rise and fall in serum magnesium resulted before the peak in serum calcium was reached, which is in accordance with the results of Scholtz (211) working with dogs. Results obtained in treating cows with early milk fever symptoms with parathyroid hormone were not encouraging. All had to be injected with calcium due to severity of symptoms before any response in blood calcium was obtained. Indications are that the failure to mobilize calcium from the skeletal reserves in milk fever may be due either to a failure of the parathyroid glands to secrete sufficient hormone or to a situation in which sufficient hormone is secreted but is rendered temporarily inactive by some metabolic condition in the tissues at parturition.

As previously mentioned, Hayden (108) and Sampson and Hayden (205) reported that the CO_2-combining power of the blood is lowered in milk fever. Craige *et al.* (46, 47, 48), on the other hand, attribute milk fever to alkalosis accompanied by increased CO_2 capacity of the blood.

It is interesting to speculate on the statement of Voinar and Babkin (255) that the narcotic anoxemia following injection of oxalic acid into narcotized dogs results in increased production and excretion of oxalic acid by the body. The possibility exists that some factor such as this may be responsible for inactivating the parathyroid hormone or tying up serum calcium at parturition. However, no conclusive evidence has been presented in support of this theory.

In connection with the possible relation of the alkaline reserve to milk fever, the work of Lecoq (138) is of interest. He has shown that in guinea pigs the intravenous injection of calcium pantothenate along with thiamin, riboflavin and adenine caused a marked increase in the alkali reserve comparable to the injection of $NaHCO_3$. Calcium pantothenate alone gave no response and when omitted the others gave no response.

Chauchard *et al.* (37) have shown that neuromuscular excitability resulted when alkalosis was induced by injecting $NaHCO_3$ (12.5 mg. three times a week) into rats. These disturbances were prevented if a simultaneous but separate dose of 800 U.S.P. units of vitamin D_2 in glycero-alcoholic solution was injected intraperitoneally. When vitamin D_2 was given with NH_4Cl, it increased the neuromuscular signs of acidosis provoked by it.

Gineste (78) presents histological evidence that the adrenal medulla action is increased by vitamin D. It is suggested that this may account for the hypertensive action of vitamin D on the whole organism.

These observations are of interest in that they shed some light on the mode of action of vitamin D in the animal body. In future research it appears that the effect of the alkaline reserve in relation to vitamin D and the parathyroid hormone might well be taken into consideration.

Sato (207) reports the presence of a substance in the blood of the mammary vein of the cow which, when injected into rabbits, has the ability to lower serum calcium.

Numerous reports such as those of Johnston (131), Robertson (195, 196, 197,

198, 199), Hunter (124), Joh (130) and Logan *et al.* (149), show that the thyroid hormone has an anabolic effect on Ca metabolism, manifested by increased calcium excretion and lowered serum calcium. In hypothyroidism the converse is true.

Prevention

The important role of vitamin D in the metabolism of calcium and phosphorus has been recognized for many years. Greig (88), Sjollema (226) and Little and Mattick (146) have suggested that vitamin D might prove beneficial as a preventive in milk fever.

In 1930, Greig (87) reported the successful treatment of 32 cases of milk fever by the intravenous injection of calcium gluconate. This discovery revolutionized the treatment of milk fever, as it was extremely effective and removed the hazards of udder inflation. In the same year, Greig (88) reported the results of his studies on the prevention of milk fever. He suggested vitamin D administration before parturition as a possible preventive measure. He fed 50,000 ostelin units (30,120 U.S.P. units) of vitamin D daily to one cow for a period of 3 wk. An increase in calcium resulted which persisted for 9 days and then returned to normal despite vitamin D administration. The serum calcium level fell below normal when vitamin D was stopped. This cow later had milk fever. The addition of calcium to the blood 5 days before parturition also was suggested (88) as a preventive measure, although little evidence was presented to support the suggestion.

Greig (92) also suggested that calcium gluconate be injected subcutaneously immediately after parturition as a prophylactic. Greig (90) reported favorable results using intramuscular injections of calcium gluconate to cure milk fever.

Hess *et al.* (116) reported no increase in the blood calcium of cows receiving 60,000 units of vitamin D daily. However, vitamin D is known to have calcemic value. Campbell and Turner (35) reported experiments in which the calcemic properties of various vitamin D preparations were tested on lactating goats. Increases in blood calcium and phosphorus were observed when A.T. 10 (Hytakerol) was injected in doses of 80 ml. over a period of 4 days. This is equivalent to 32,000,000 I.U. of vitamin D. A.T. 10 has a calcemic value twice that of calciferol. These authors also suggested the possibility of utilizing the calcemic properties of vitamin D to buffer the sudden demands for calcium mobilization and increased parathyroid activity at parturition and beginning lactation, thereby lessening the danger of milk fever.

Campbell and Turner (35) confirmed and extended the observations of Bastenie and Zylberzac (20) that high doses of A.T. 10 were toxic to rats and that parathyroid activity actually is suppressed by excessive doses. Blood calcium levels of 18 to 20 mg. per 100 ml. were found in the toxic rats. Hess *et al.* (116) had observed no toxic symptoms in cows fed as much as 1,500,000 units of vitamin D daily.

Campbell and Turner (35) showed that vitamin D administration causes a decrease in the animal's own parathyroid activity when fed for long periods of time. In other words, there is a strong tendency for the animal to maintain a

normal blood calcium level and if this is accomplished with supplemental vitamin D or high calcium rations, then the cow's own parathyroid gland is not needed and lapses into a hypoactive state. Therefore it seems reasonable that if vitamin D were fed in large amounts for too long a time, the animal's own calcium-mobilizing power may be suppressed to the point that the beneficial or supplemental action of the vitamin D feeding on calcium mobilization would be nullified.

Under these conditions when parturition and beginning lactation occur, the cow would be in no better condition to meet the sudden demand for calcium than if no vitamin D were fed. Thus, it is apparent that in the use of vitamin D as a possible preventive in milk fever, care should be exercised in selecting a dosage which would be non-toxic and one which would supplement rather than depress parathyroid activity.

In earlier experiments conducted by Hibbs *et al.* (119, 120) no reduction in milk fever incidence was obtained from feeding from 1 to 5 million units of vitamin D daily for from 2 to 4 weeks prepartum. Although blood calcium was increased considerably at the higher levels of vitamin D feeding just prior to parturition, the increase was nullified within 24 hr. postpartum in normally freshening cows.

In more recent experiments, a part of which has been reported by Hibbs *et al.* (118), massive doses of vitamin D have been administered limiting the dosage to the period of a few days just prior to parturition. It was reasoned that by timing the dosage so that the peak in the blood calcium level was reached just prior to parturition, the vitamin D would have the maximum supplemental action without possible parathyroid suppression due to prolonged elevated blood calcium. The results to date based on the blood changes in calcium, phosphorus and magnesium and on the incidence of milk fever have been most gratifying. It is believed that an effective, practical, preventive measure for milk fever can be based on these findings.

SUMMARY AND CONCLUSIONS

The history of milk fever (parturient paresis), traced from the time reports first began to appear in the literature (about 1793) indicates that this metabolic disturbance has been associated with the development of the dairy cow for high milk production. Some thirty theories of the etiology of milk fever have been advanced through the years. As new scientific knowledge and techniques have developed, the false hypotheses gradually have been eliminated so that a complete understanding of the fundamental basis of milk fever now awaits only the proof of certain points in the present concept which now are based on circumstantial evidence.

The evidence indicates that the lowered blood calcium in milk fever is due to the failure of the blood calcium regulatory mechanism to mobilize calcium from the tissue reserves rapidly enough to equal the withdrawal of calcium from the blood into the udder secretions.

If it is assumed, as the evidence indicates, that the parathyroid hormone is the primary regulator of blood calcium, its failure in milk fever may be caused

by either parathyroid inadequacy resulting in the lack of sufficient hormone secretion or by the presence of some metabolic condition in the tissues at parturition that renders the parathyroid hormone temporarily inactive. It would seem, therefore, that further work on the function of the parathyroid glands at parturition must be done before the fundamental basis of milk fever can be proven.

Any preventive measure must be aimed at eliminating the precipitous fall in blood calcium at parturition. Vitamin D in large amounts just prior to parturition offers the most encouraging possibilities for prevention. However, it is not known as yet whether the vitamin D acts to increase blood calcium *per se* or *via* the parathyroid glands.

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ABSTRACTS OF LITERATURE

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BOOK REVIEW

689. Annual Review of Biochemistry, vol. XIX. J. M. LUCK, editor. Annual Reviews, Inc., Stanford, Calif. 596 pp. $6.00. 1950.

The topics covered are: Biological oxidations, V. R. Potter; Proteolytic enzymes, M. Laskowski; Nonoxidative, nonproteolytic enzymes, P. P. Cohen and R. W. McGilvery; Carbohydrate chemistry, M. L. Wolfram and J. M. Sugihara; Chemistry of lipids, H. J. Deuel, Jr.; Chemistry and metabolism of the steroid hormones, G. Pincus; Chemistry of amino acids and proteins, R. K. Cannan and M. Levy; Nucleic acids, purines and pyrimidines, G. Schmidt; Carbohydrate metabolism, S. Ratner and E. Racker; Fat metabolism, G. Medes; Metabolism of proteins and amino acids, P. P. Swanson and H. E. Clark; Chemistry of the hormones, A. White; Water-soluble vitamins, E. E. Snell and L. D. Wright; Fat-soluble vitamins, T. Moore; Nutrition, H. M. Sinclair; Muscle, F. B. Straub; Biochemistry of neoplastic tissue, C. Carruthers; Chemical composition of blood plasma and serum, H. A. Krebs; Pyrrole pigments, R. Lemberg and J. W. Legge; Immunochemistry, P. Grabar; Biochemistry of antibiotics, H. E. Carter and J. H. Ford; and Partition chromatography, A. J. P. Martin.

As is usual in this series of publications, the authors have restricted their coverage somewhat more than the title would indicate in a number of instances. The reviews in general cover the material appearing during 1949, although earlier material is included in a number of cases where a topic has not been reviewed regularly.

The reviews on the whole are up to the high standards which one has come to expect of this publication. The subject and author indices are adequate. This is a very valuable reference book for any one working in the more fundamental areas of dairy science, as well as for others in biology and biochemistry. F. E. Nelson

ANIMAL DISEASES

W. D. POUNDEN, SECTION EDITOR

690. Ketosis and the dairy cow. C. B. KNODT. Penn. State College, State College. Milk Plant Monthly, 39, 8: 76–77. Aug., 1950.

Ketosis and its relation to "cowy" flavor in milk is discussed. Symptoms and methods of treating the disease also are included.

J. A. Meiser, Jr.

691. Some clinical uses of a new antihistamine. G. R. MOORE, Mich. State College, East Lansing. Vet. Med., **45:** 328–329. Aug., 1950.

A brief report is presented on the use of a new antihistamine drug (dimethylaminoethoxy-methylbenzyl-pyridine succinate) in the treatment of livestock for certain animal diseases. Two of 3 cases of bovine stomatitis showed improvement, also 3 out of 6 cases of chronic calf scours. Four cases of persistent bloat were treated and the antihistamine therapy was of value. Three cases of bloat in 5–7-mo.-old calves were relieved by a single intravenous injection. Symptoms were relieved in cases of retained placenta and respiratory infections in cattle. B. B. Morgan

692. Occurrence of the ear mite, Raillietia auris (Leidy, 1872), of cattle in Colorado. O. W. OLSON and F. K. BRACKEN. Colo. State College Fort Collins. Vet. Med., **45:** 320–321. Aug., 1950.

This is the first report of ear mites (*R. auris*) in cattle since the original description by Leidy in 1872. The mites were found in the tympanic membrane. Clinical symptoms included obvious distress, the head was held in an extended position and twisted to one side to give the impression that the animal was listening to sounds near the ground. Other symptoms were emaciation

and anorexia. The animal was sacrificed and at autopsy mites were recovered from the bulla tympanica. B. B. Morgan

693. Veterinarians' role in public health. J. H. Steele, U. S. Public Health Service, Atlanta, Ga. Vet. Med., **45:** 311–312. Aug., 1950.

The role of the veterinarian in the safeguarding of human health by the control of animal diseases is reviewed. Important diseases mentioned include bovine tuberculosis, brucellosis, rabies, trichinosis, Q fever and swine influenza. Brucellosis is still the main occupational disease of veterinarians. Only milk from brucellosis-free herds should be permitted to be sold as grade A.
B. B. Morgan

BUTTER

O. F. HUNZIKER, SECTION EDITOR

694. Mottle in butter. L. L. Muller, Dept. of Agr., Brisbane, Australia. Australian J. Dairy Technol., **4,** 1: 7–8. Jan.–Mar., 1949.

A special microscopic technique for observation of moisture droplets in butter is described. Butter is smeared between a slide and coverslip, the latter supported by 2 strips of gold leaf cemented to the slide. A chamber approx. 30μ in depth thus was obtained and served to reduce materially distortion of the droplets. A photomicrograph of a portion of a deep yellow patch of mottled butter is shown which clearly depicts large water droplets containing undissolved salt crystals. The contrast between these and normal-sized water droplets also may be observed. The factors governing mottling in butter are reemphasized.
J. C. Olson

695. Plant and equipment sanitation in relation to butter quality. E. G. Hood. Can. Dairy Ice Cream J., **29,** 6: 27–31. June, 1950.

The most commonly encountered flavor defects recorded in Canadian butter were: surface taint, fishy tendency, tallowy or oxidized, rancid, surface flavor, unclean off-flavors, stale, yeasty, barny and malty. Mold and bacterial surface discoloration also has been common. The majority of defects were found to be associated with the microbiological flora of the butter. Experimental work has shown that recontamination from equipment after pasteurization may completely offset the beneficial effects of pasteurization. Other factors affecting the growth of bacteria in butter are temperature of holding, salt content, extent of working the butter, care of equipment, care of churn, sterilization treatment, air contamination, purity of wash water and general plant sanitation.
H. Pyenson

696. Variable speed churn and butter worker. F. G. Cornell, Jr. (assignor to General Dairy Equipment Co.). U. S. Patent 2,514,375. 9 claims. July 11, 1950. Official Gaz. U. S. Pat. Office, **636,** 2: 459. 1950.

A cube-shaped churn with the corners cut off, rotates about a diagonal axis. Access to the churn is through a manhole in 1 side.
R. Whitaker

697. Questions and answers about the water insoluble acids and butyric acid tests for butter and cream. W. H. Martin and T. J. Claydon, Kansas State College, Manhattan, R. Alberts, Am. Butter Inst., A. C. Keith, Latimore Lab., Topeka, Kansas. Butter, Cheese & Milk Prod. J., **41,** 7: 22–23, 58–60. July, 1950.

A panel of experts has answered 28 of the most common inquiries concerning the W.I.A. test and butyric acid test to determine the quality of cream and butter. The discussion considers methods, reliability and interpretation of the results of the test. H. E. Calbert

698. Margarine sales cutting producer income. J. S. Turnbull. Can. Dairy Ice Cream J., **29,** 39–40, 42. June, 1950.

The Canadian government is faced with the task of attempting to protect the producer of butterfat through the medium of a floor under creamery butter. The author takes the view that practical controls over the manufacture and sale of margarine would be sufficient to protect the butter producer. Attempts should be made to divert milk production to other manufactured products. The consumer demand for butter should be increased. H. Pyenson

CONDENSED AND DRIED MILKS; BY-PRODUCTS

F. J. DOAN, SECTION EDITOR

699. Use and properties of non-fat dry milk solids in food preparation. I. Effect on viscosity and gel strength. Lura M. Morse, Dorothy S. Davis and E. L. Jack. U. of Cal., Davis. Food Research, **15,** 3: 200–215. May–June, 1950.

Use of dry milk in baked products primarily from the standpoint of effect on body and viscosity of batters, doughs and pastes is reported. Dry milk increases gel strength and viscosity of mixtures in proportion to amounts added, but compensatory adjustments may be made by reducing the amount of flour used. Line graphs are given from which body and viscosity values may be predicted. Sugar decreases gel strength as a rule

but increases viscosity. Fat and salt have lesser effects in somewhat the same directions. Decreases in pH lower the viscosity and gel strength, often curdling thin pastes, but pH increases up to pH 8.0 exhibit inconsistent results. F. J. Doan

700. Use and properties of non-fat dry milk solids in food preparation. II. Use in typical foods. Lura M. Morse, Dorothy S. Davis and E. L. Jack. U. of Cal., Davis. Food Research, **15,** 3: 216–222. May–June, 1950.

The optimum quantities of dry milk are determined for use in such foods as cream soups, custards, white sauces, chocolate puddings, egg nogs, waffles and angel, butter-sponge and plain butter cakes. Dry milk can be used to advantage in each case for improving both nutritional quality and palatability of the product. F. J. Doan

701. Use of whey in bakery goods. L. V. Rogers, Dairy Prod. Research Lab. U.S.D.A. Natl. Butter & Cheese J., **41,** 3: 31. Mar., 1950.

Since fluid whey contains half the solids of the milk, it is desirable from the nutritional standpoint to use it in the production of foods. Either fresh fluid, condensed or dried whey can be used in the production of sherbets, cheese foods and bakery goods. Doughs using whey produce the more tender cakes and cookies. Doughnuts made with whey remain soft and retain their good eating qualities for a longer period. The milk sugar of the whey aids in the development of a uniform brown crust on baked goods. Formulas for the use of whey in baked goods can be obtained from the Division of Dairy Products Research Laboratories, Bureau of Dairy Industry, U.S.D.A., Washington 25, D. C. H. E. Calbert

702. Consumer acceptance of bread containing different amounts of nonfat dry milk solids. E. L. Jack, Univ. of Cal., Davis. Butter, Cheese & Milk Prod. J., **41,** 5: 27. May, 1950.

Breads containing 0, 6, 10 and 14% nonfat dry milk solids were fed to a group of 320 boys ages 8–16 yr. A bread containing each level of nonfat dry milk solids was fed for a period of 8 wk. until the cycle was completed. The 8-wk. intervals were varied to eliminate any seasonal variations that might influence bread consumption. As the amount of nonfat dry milk solids in the bread increased, the bread consumption also increased. The increases in bread consumption averaged as follows: 6% level, consumption increased 4.4%; 10% level, consumption increased 7.1%; 14% level, consumption increased 12.6%. H. E. Calbert

703. Studies on the reconstitutability of whole milk powder. U. S. Ashworth and R. Hibbs. Can. Dairy Ice Cream J., **29,** 6: 84–86. June, 1950.

There is strong indication that the typical powdered milk flavor is one of the effects of slight insolubility. Stale flavor can be shown to be associated with the development of insolubility during storage. Whole milk powder evaporated to 40% T.S. is more soluble than whole milk powder evaporated to 20% T.S. before drying. None of the wetting agents used were very successful in improving the rate of dispersion of a typical spray-dried whole milk powder. Other studies show that the rate of dispersion of lactose and protein are similar. H. Pyenson

704. Mixing device. G. D. Turnbow and A. V. Osborne (assignors to Chester-Jensen Co.). U. S. Patent 2,513,382. 3 claims. July 4, 1950. Official Gaz. U. S. Pat. Office, **636,** 1: 115. 1950.

This device was designed to reconstitute powdered milk with water in commercial quantities without making a foam. The powdered milk is metered from a supply tank erected above the mixing vat and flows downward into a cylinder partially submerged in the water in the mixing vat. A rotating agitator revolves in the cylinder, drawing water in through ports, suspending the powder and forcing the reconstituted milk out a lower set of ports into the mixing vat. A propellor-type agitator in the vat insures uniformity of the mixing vat contents. R. Whitaker

705. How to prepare and store skim milk for use in ice cream. B. H. Webb, U.S.D.A. Am. Milk Rev., **12,** 2: 46–49. Feb., 1950.

Skim milk may be stored as plain condensed, superheated condensed, frozen condensed, sweetened condensed, low lactose condensed and dried. Detailed processing procedures are omitted but attention is called to the importance of the effect of temperature on viscosity and protein stability as these in turn influence the storage life of the product. D. J. Hankinson

706. Expanding the market for non-fat dry milk solids. B. W. Fairbanks. Can. Dairy Ice Cream J., **29,** 6: 52–56. June, 1950.

Three ways open in 1950 to expand domestic market for non-fat dry solids are to increase commerical exports, to increase sales in domestic market and to continue to sell to the government under the price support program (it may not last). H. Pyenson

707. Milk powder industry sins source of manufactures' problems. H. LAMARCHE. Can. Dairy Ice Cream J., **29,** 6: 80–82. June, 1950.

The home and abroad competition would be easy to meet and there would be no more overproduction of milk powder if the cost of production was controlled, the quality of the product was improved and the distribution was made more adequate. H. Pyenson

708. Apparatus for turning milk. M. E. LAWRENCE. U. S. Patent 2,511,643. 1 claim. June 13, 1950. Official Gaz. U. S. Pat. Office, **635,** 2: 604. 1950.

A small insulated box holds a can of milk for the purpose of producing a desirable clabber on souring. The temperature is maintained automatically at 85° F. by a thermostatically-operated electric light bulb situated below the can.
R. Whitaker

Also see abs. no. 758.

DAIRY BACTERIOLOGY

P. R. ELLIKER, SECTION EDITOR

709. Effect of reducing substances on starter culture action in agitated and unagitated milk. H. KATZNELSON and E. G. HOOD. Can. Dairy Ice Cream J., **29,** 7: 27–28. 1950.

Glutathione functions as a hydrogen donator and serves primarily to poise the oxidation-reduction potential in agitated milk at a level which permits normal development of the lactic streptococci. Cysteine and glutathione stimulated acid production by a starter culture in 24-hr.-old pasteurized milk which had received some agitation, but only glutathione caused an increase in the unagitated milk with the 5 starter cultures tested; the 4 consistently produced lower acid in agitated milk, an effect which was overcome by glutathione; a single strain starter was not affected appreciably by aeration. Starter action in unagitated pasteurized milk, 24-hr.-old, was stimulater by glutathione, the effect being even more marked when the milk was agitated. Glutathione exerted its effect when added at the beginning of incubation of inoculated milk but not when added 2 hr. later. H. Pyenson

710. Preparing and maintaining good cultures. N. C. ANGEVINE, Meyer-Blanke Co., St. Louis, Mo. Milk Dealer, **39,** 10: 58, 62–68. July, 1950.

See abs. no. 414.

711. Penicillin in milk. W. A. KRIENKE, Fla. Agr. Expt. Sta., Gainesville. Am. Milk Rev., **11,** 12: 24–25. Dec., 1949.

See abs. no. 152.

712. Effects of various "drugs" in milk from mastitis-treated cows on acid production by lactic starters. W. A. KRIENKE, Fla. Agr. Expt. Sta., Gainesville. Milk Dealer, **39,** 7: 50, 72–75. Apr., 1950.

Whether unheated or heated as high as 241° F. for 15 min., milk containing 5 ml. of a 25% solution of sulfamethazine/100 ml. permitted practically no acid production by a buttermilk culture during 18 hr. incubation at 70° F. When the drug was present in the amount of 1 ml. of 25% solution/100 ml. of milk, there was some acid development, which in the milk pasteurized at 143° F. for 30 min. was only slightly above 0.35% titratable acidity. Reduction to 0.1 ml. of 25% solution/100 ml. of milk permitted acid development to 0.46% compared to 0.71% for the control.

After incubation for 18 hr. at 70° F. or for 7 hr. at 95° F., there was practically no acid production when the milk containing 0.0005 mg. of aureomycin hydrochloride/ml. had been pasteurized at 143° F. for 30 min. When the concentration of the "drug" was reduced to 0.00005 mg./ml. of milk, acid production was nearly normal as compared to that of the control samples. At 95° F., a sample containing an intermediate concentration of the aureomycin hydrochloride gave considerably less acid production than did the control. These results emphasize the necessity of eliminating milk containing aureomycin from the supply to be used for cultures and fermented dairy products. C. J. Babcock

713. Some recent adavnces in the bacteriology of pasteurized milk. E. B. ANDERSON and L. J. MEANWELL, United Dairies, Ltd., Central Lab., London. J. Sci. Food & Agr., **1,** 3: 77–80. Mar., 1950.

During 1 yr., 18,411 samples of raw milk were examined for methylene blue reduction time and for keeping quality of the corresponding laboratory pasteurized milk. The keeping quality was measured in terms of the per cent titratable acidity (as lactic acid) after incubation at 26° C. for 24 hr. A direct relationship was found between reduction time of raw milk and keeping quality of the corresponding pasteurized milk. Raw milk collected at atmospheric temperatures above 21° C. gave, on the average, poorer pasteurized milk-keeping quality than raw milk collected at lower temperatures, even when the raw milk quality as measured by methylene blue was the same. With bulked milk drawn from farms where utensil sterilization was practised, the keeping quality of the corresponding pasteurized milk was greater throughout the year than that of

bulked milk drawn from farms where the practice of utensil sterilization was questionable.

E. B. Collins

714. A comparative study of presumptive media for the coliform group. H. J. FOURNELLE and H. MACY, Univ. of Minn., St. Paul. Am. J. Pub. Health, **40,** 8: 934–942. Aug., 1950.

A study was made of certain media, including brilliant green bile broth, formate ricinoleate broth, violet red bile agar, desoxycholate agar and desoxycholate lactose agar, to determine which would support the best growth of coliform organisms. In 15 comparative tests, where these media were inoculated with pure cultures of coliform organisms, the counts obtained with both the liquid and solid media agreed fairly closely for any 1 culture. An equal number of trials were made in which the media were inoculated with samples of milk and cream positve for the coliform organisms. Results obtained in this latter series of tests varied from close agreement to wide differences with the same sample. A definite order of productiveness could not be determined for the liquid and solid media together in either series of tests, because of the variable results. Desoxycholate agar seemed to be the least productive of the media studied, although in most instances the differences were not great.

The bacteriostatic effect of the dyes used in these media also was checked. Brilliant green was slightly more inhibitory than crystal violet, although the effective concentrations of both were considerably greater than that used in the media. Sodium ricinoleate showed little bacteriostatic action in a concentration of less than 1:25. Sodium desoxycholate was inhibitory in concentrations of less than 1:50 up to 1:1,000. This latter concentration is customary in desoxycholate agar.

D. D. Deane

715. Coliform, their significance and control in ice cream making. G. W. SHADWICK, Beatrice Foods Co., Chicago, Ill. Am. Milk Rev., **11,** 12: 40–41. Dec., 1949.

See abs. no. 441 (1949).

DAIRY ENGINEERING

A. W. FARRALL, SECTION EDITOR

716. Process for treating potable liquids. F. S. BOARD and R. P. ROBICHAUX (assignors to Murray Deodorizers, Ltd.). U. S. Patent 2,516,099. 5 claims. July 25, 1950. Official Gaz. U. S. Pat. Office, **636,** 4: 1158. 1950.

Fluid dairy products are preheated to 110–160° F., then steam is injected to 162-185° F. while the fluid is passing through a vacuum zone ranging from 12–20 in. of Hg, then through a second vacuum zone ranging from 13–21 in. Hg for withdrawing vapors and gases. Following a 15-sec. holding period at 160–183° F. to effect pasteurization, the deodorized product is vacuum cooled.

R. Whitaker

717. Freezing, hardening and dispensing cabinet and containers therefor. L. A. M. PHELAN. U. S. Patent 2,517,234. 3 claims. Aug. 1, 1950. Official Gaz. U. S. Pat. Office, **637,** 1: 177. 1950.

A refrigerated cabinet provides refrigeration for a counter freezer mounted on top, a low-temperature hardening space and a dispensing compartment operating at dipping temperature.

R. Whitaker

718. Agitating device for making frozen desserts. W. B. MCGORUM. U. S. Patent 2,516,-232. 13 claims. July 25, 1950. Official Gaz. U. S. Pat. Office, **636,** 4: 1191. 1950.

A motor-driven agitator for stirring mix, etc. in a tray in a household refrigerator freezing compartment is described.

R. Whitaker

719. Apparatus for agitating and dispensing frozen foods. T. CARVEL U. S. Patent 2,491,-852. 6 claims. Dec. 20, 1949. Official Gaz. U. S. Pat. Office, **629,** 3: 758. 1950.

Structural features are given for a freezer to manufacture soft ice cream and frozen custard. Mix is introduced into the rear of a horizontal cylindrical freezer where it is whipped with air, frozen and propelled toward the front of the freezer where it is withdrawn through a gate valve.

R. Whitaker

720. Capping machine. H. G. VORE (assignor to American Seal-Kap Corp.). U. S. Patent 2,516,278. 4 claims. July 25, 1950. Official Gaz. U. S. Pat. Office, **636,** 4: 1203. 1950.

Preformed skirted hood caps, impregnated with a thermoplastic adhesive, are heated as they pass through a high frequency electrostatic field, then placed on milk bottles and held in place until heat-sealed.

R. Whitaker

721. Freezer. L. S. MARANZ (assignor to Freeze King Corp.). U. S. Patent 2,515,722. 11 claims. July 18, 1950. Official Gaz. U. S. Pat. Office, **636,** 3: 934 1950.

An arrangement on an ice cream or frozen custard freezer introduces mix from a supply tank into the freezing chamber. R. Whitaker

722. Brine overflow attachment for ice cream freezers. R. C. NIERSTE. U. S. Patent 2,514,787. 1 claim. July 11, 1950. Official Gaz. U. S. Pat. Office, **636,** 2: 565. 1950.

To prevent brine from contaminating ice cream frozen in a verticle ice and salt freezer, an outer container is provided into which the brine overflows. R. Whitaker

723. Emulsifying machine. R. E. GODSBROUGH. U. S. Patent 2,514,992. 2 claims. July 11, 1950. Official Gaz. U. S. Pat. Office, **636,** 2: 621. 1950.

A small capacity, 1-piston homogenizer has a built-in supply tank equipped with an agitator to premix the material and keep it uniform. A 2-stage homogenizing effect is obtained as the product is released through a series of slots after passage through a spring-loaded valve. R. Whitaker

724. Cooking apparatus. N. J. PETERS (assignor to Damrow Bros. Co.). U. S. Patent 2,514,008. 1 claim. July 4, 1950. Official Gaz. U. S. Pat. Office, **636,** 1: 279. 1950.

A horizontal screw-type cooker of the type suitable for making such products as process cheese has bearings so designed that the screw shaft may be removed from the trough for cleaning. R. Whitaker

725. Licking the ice and snow problem on loading platforms. Anonymous. Natl. Butter & Cheese J., **41,** 3: 38. Mar., 1950.

The use of iron pipe heating coils to melt snow and ice by placing them under the floor of the loading platform is illustrated. H. E. Calbert

726. Maintenance of calcium chloride brine. Anonymous. Milk Plant Monthly, **39,** 6: 84–87. June, 1950.

Factors to be considered in the routine maintenance of refrigerating brines are proper strength, sufficient volume, freedom from ammonia, proper alkalinity and use of corrosion inhibitors. Detailed procedures for testing brine and tables for strengthening brine with $CaCl_2$ are included in this article. J. A. Meiser, Jr.

727. Rust, billion dollar rat hole. J. HOWARD. Am. Milk Rev., **11,** 12: 26, 28, 43. Dec., 1949.

Rust and corrosion are a form of destruction of equipment, its cost annually in the world being estimated at upwards of 10 billion dollars. An estimated 2% of the entire tonnage of iron and steel in service must be replaced each year because of loss through rust. Two corrosion control measures are described. One measure is to use corrosion-resistant alloys, such as stainless steel. The other is to use a protective coating. An improved deodorized and pre-oxidized fish oil is claimed to have considerable merit, particularly because it can be applied directly over a rusted surface. This oil will carry pigment, enabling its use as a final coat. D. J. Hankinson

728. The problem of water scale formation. W. F. BENSON, Limex Corp., Indianapolis. Natl. Butter & Cheese J., **41,** 4: 34, 54. Apr., 1950.

The composition and amount of solids present in water that cause scale formation vary considerably throughout the country. The most common cause of scale formation is bicarbonate alkalinity that exists because of the amount of CO_2 in solution. There is a balanced relation between soluble $Ca(HCO_3)_2$, gaseous CO_2 and insoluble $CaCO_3$. The removal of CO_2 by increased temperature, aeration or alkalinity promotes scale formation. These causes for the removal of CO_2 cannot be prevented in ordinary operations. Therefore, water treatment is necessary to prevent the formation of scale on plant equipment. During the past 10 yr., several satisfactory water-treatment systems have been developed that are suitable for the average dairy plant. H. E. Calbert

729. How to pick the right valve. J. MEYER, Minneapolis-Honeywell Regulator Co., Philadelphia, Pa. Am. Milk Rev., **12,** 2: 34-37. Feb., 1950.

Valves either are hand-operated or automatic. Hand-operated valves are of the quick-opening or the proportional type. Proportional valves permit throttling control of the flowing medium. Automatic valves are diaphragm motor-operated (pneumatic), electric motor-operated or solenoid-operated. Many dairy plant operations are controlled by valve action. The valve engineer attempts to correlate price and performance in selecting the proper type of valve. In addition to proper design, high quality materials and satisfactory operation, the dairy company must be assured of repair service and replacement parts when needed. D. J. Hankinson

Also see abs. no. 696.

DAIRY PLANT MANAGEMENT AND ECONOMICS

L. C. THOMSEN, SECTION EDITOR

730. Milk and fat losses in processing fluid milk. J. S. PFAUTZ, Penn. Milk Control Commission,

Harrisburg, Pa. Milk Dealer, **39,** 10: 45-47, 85-95. July, 1950.

The butterfat and product pounds lost in the operation of a milk pasteurization plant are shown for the month of Sept., 1949. They are based on the total receipts in product pounds and butterfat pounds for 118 dealers handling 183,889,948 lb. of milk and milk products which represents from 65–68% of all the milk handled in the state of Pennsylvania. On the annual basis of these 118 dealers, the total cost of fat lost for all dealers, at the present support price of approximately 74¢/lb., would be approximately $1,100,000 annually. Data is presented which summarizes the various products into standard milk. The routes are classified into retail and wholesale; returns of milk and cream were 4.63% for retail and 2.75% for wholesale routes. Data are given which show the loss in dumping of packaged milk and cream, loss in separating dumped milk and cream, the relation of the cost of dumped milk and cream to annual profit, receiving losses, filling losses, refrigerator losses, etc. C. J. Babcock

731. Inventory control for the milk plant. F. Merish. Milk Plant Monthly, **39,** 8: 32, 34-36. Aug., 1950.

Fifteen sound reasons for the need of inventory control are discussed. Also included are certain forms for recording inventory date.
J. A. Meiser, Jr.

732. What happens to the profits? M. J. Kluger, Kapleau, Kluger and Co., Philadelphia, Pa. Am Milk Rev., **11,** 12: 2, 3, 4, 6. Dec., 1949.

This accountant's analysis of a firm's profit level makes use of another statement, the statement of sources and application of funds, in addition to the usual ones. This statement tells management if profits and other funds are properly used. Profits should not be confused with cash in the bank. D. J. Hankinson

733. The pallet system of material handling for the processing plants. L. H. Heckendorn. Milk Plant Monthly, **39,** 6: 28-30, 32, 34. June, 1950.

As milk arrives in the cold box from conveyors, the cases are placed on pallets according to the driver's predetermined orders. At loading time, fork lift trucks transport the pallets to the delivery truck where the machine deposits its load. Empty bottle returns are stacked on pallets and removed by the mechanical lift to the conveyor feeding the bottle washer or stacked while awaiting washing. Cases may be tiered 12-15 case high on pallets without difficulty. Advantages of this system are that it: (a) reduces daily labor requirements, (b) speeds up loading and unloading of vehicles, (c) may be used for handling incoming supplies, (d) utilizes floor space more efficiently, (e) reduces length of conveyor lines, (f) reduces inventory losses and breakages caused by conveyor systems and (g) has flexibility. J. A. Meiser, Jr.

734. Dairy laundry reduces operating costs. J. Lee, Abbotts Dairies, Philadelphia, Pa. Milk Plant Monthly, **39,** 8: 46-47. Aug., 1950.

Dairy laundries reduce actual operating costs and eliminate waiting periods between pickup and delivery. Since about 90% of the work involves rough drying only, a limited amount of equipment is needed for starching and flatironing. Shipment of soiled and laundered clothes to and from the laundry is in locked drums. By working from 5:30 a.m. to 1:30 p.m., these drums containing laundered clothes can be returned the same day. J. A. Meiser, Jr.

735. Inter-dependency of dairy industry stressed. W. F. Jones. Can. Dairy Ice Cream J., **29,** 6: 41-42. June, 1950.

The more important factors which will have a decided influence on the long term position of the dairy industry are: (a) the extent to which substitutes are permitted to enter into competition with butter and other dairy products; (b) the level at which our national income and consumer purchasing power is maintained; (c) the prices at which dairy products are made available to consumers; (d) the availability and prevailing price levels in export markets for our surplus products; (e) the degree of government intervention in the marketing of our products; and (f) the extent to which we are prepared to promote the sale of our products in face of the ever-increasing competition for the consumer's food dollar. H. Pyenson

736. Abundant production wisely used. C. F. Brannan, Secty. of Agr. Am. Milk Rev., **12,** 2: 5-6, 10, 65. Feb., 1950.

Attention is called to the declining purchasing power of farm dairy products. Farmers deserve a fair return: therefore, a support program is needed. The purchase storage method of support is criticized because the consumer pays twice, once in the form of higher prices and again in the form of higer taxes. Instead, it is proposed that farmers be paid directly the difference between the average market price and the support level for the particular area. The support level would be based on the average purchasing power of cash

receipts from farm marketing during a recent 10-yr. period. This proposal has become known as the Brannan Plan. D. J. Hankinson

737. History of dairy legislation key to dairy industry's progress. H. F. Grieg. Can. Dairy Ice Cream J., **29,** 7: 42-50. July, 1950.

Progress in dairy technology down through the years has been associated with 1 or a combination of 3 things: (a) the development of new tests, (b) the advance in dairy engineering and (c) the advent with each succeeding generation of new thinkers capable of grasping the advantages which the progress of the previous generation may have afforded. The author gives a summation of the dairy industry and the legislation which has played a part in the progress of milk products. H. Pyenson

HERD MANAGEMENT

H. A. HERMAN, SECTION EDITOR

738. Eliminating feed flavors during the grassy season. F. Flagg. Milk Plant Monthly, **39,** 7: 34-35. July, 1950.

Mixing 1 can of grassy milk with 2,000 gal. of normal milk has been known to impart an objectionable flavor and odor to milk. This dairy attempted to eliminate this summer problem by mailing letters to producers in Feb. and March. Feb. correspondence explained how to control off-flavors in milk, and the March letters informed producers that no abnormal milk would be accepted. First offenders would be warned; second offenders would be suspended for 3 d.; and third offenders would be permanently excluded from shipping milk during the grassy season. This eliminated about 10% of the producers, although all but a few returned after control was gained. J. A. Meiser, Jr.

739. Milking machine pulsator. R. W. Lemm. U. S. Patent 2,517,327. 4 claims. Aug. 1, 1950. Official Gaz. U. S. Pat. Office, **637,** 1: 201. 1950.

A device for producing pulsations in the vacuum supply of a milking machine is described. R. Whitaker

740. Pulsator apparatus for milking machines. J. R. Lowry. U. S. Patent 2, 516, 328. 1 claim. July 25, 1950. Official Gaz. U. S. Pat. Office, **636,** 4: 1216. 1950.

A self-contained milking machine on a small truck may be rolled from cow to cow. A motor-driven piston-type pulsator provides intermittent vacuum. The milk is collected directly in a milk can on the truck. R. Whitaker

741. Pulsator apparatus for milking machines. P. A. Taylor (assignor to Ideal Mfg. Co.). U. S. Patent 2, 516,354. 1 claim. July 25, 1950. Official Gaz. U. S. Pat. Office, **636,** 4: 1222. 1950.

Similar to abstract 740, but differing in mode of controlling pulsations. R. Whitaker

742. Milk claw. E. Shurts. U. S. Patent 2,514,676. 3 claims. July 11, 1950. Official Gaz. U. S. Pat. Office, **636,** 2: 537. 1950.

A manifold for milking machines with 4 outlets for attaching to teat cups is so designed that all interior surfaces may be inspected visually for sanitary condition. R. Whitaker

743. Milk strainer. D. O. Brant. U. S. Patent 2,516,102. 2 claims. July 25, 1950. Official Gaz. U. S. Pat. Office, **636,** 4: 1159. 1950.

A farmer's milk strainer in which the filter pad is held in place by a perforated rubber disk is described. R. Whitaker

744. Dehorner. W. I. Coull. U. S. Patent 2,516,959. Aug. 1, 1950. Official Gaz. U. S. Pat. Office, **637,** 1: 106. 1950.

The horns of cattle are cut off by a blade which swings across a plate with a hole in it, the horn being inserted in the hole. R. Whitaker

745. Mechanical barn cleaner. L. E. Peterson. U. S. Patent 2,516,798. 2 claims. July 25, 1950. Official Gaz. U. S. Pat. Office, **636,** 4: 1335. 1950.

A device collects the material in a barn gutter and delivers it into a carrier or up on a pile located some point beyond the end of the gutter. R. Whitaker

746. Cow tail holder. A. J. Arends. U. S. Patent 2,516,744. 1 claim. July 25, 1950. Official Gaz. U. S. Pat. Office, **636,** 4: 1320. 1950.

This device restrains a cow from swishing her tail. R. Whitaker

747. Sucking device for calves. P. O. Stevens (assignor to Mutual Products Co.). U. S. Patent 2,516,730. 2 claims. July 25, 1950. Official Gaz. U. S. Pat. Office, **636,** 4: 1317. 1950.

A vertical plate attached to a pail holds a tube which extends downward into liquid calf food in the pail. The upper end of the tube extends horizontally through the plate and terminates in a nipple. R. Whitaker

ICE CREAM

C. D. DAHLE, SECTION EDITOR

748. How, why and when ice cream gets into the home. Anonymous. Ice Cream Trade J., **46,** 7: 34-36, 38, 95, 96. July, 1950.

The American Dairy Association has just completed a market study based on interviews with the buying public and with manufacturer's retail outlets. The housewife buys 46% of the ice cream, while her husband purchases only 18%. Saturday is the most important day for ice cream purchases, while Friday and Saturday represent 50% of the "take home" purchases. Drug and food stores are the leading outlets and 4-8 p.m. are the hours of greatest purchases. Convenience determines why ice cream is bought at a certain outlet with brand preference a close second. Ice cream is being served in the home as a mealtime dish and backbar streamers rated the most effective advertising. W. H. Martin

749. Sorbitol used in ice cream for diabetics. P. H. Tracy and G. Edman, Univ. of Ill., Urbana. Ice Cream Trade J., **46,** 7: 50-52, 83-84. July 1950.

Research aimed at improving the existing low-carbohydrate ice cream formula for this country's million diabetics has been conducted using hexahydric alcohol (sorbitol) as the source of sweetness. This compound is a member of the "sugar-alcohols" and is produced commercially by adding hydrogen to the aldehyde or ketone group of a sugar molecule. The value of sorbitol as a sweetener lies in the delay before it appears in the blood as glucose and its low carbohydrate and insulin demand values. Sixteen lb. of sorbitol solution and 5 g. of saccharin/100 lb. of mix produces ice cream of good body and sweetness comparable to a 14% sucrose ice cream. A good diabetic ice cream is produced using 17% fat, 5.1% s.n.f., 5% whole eggs, 16% sorbitol solution and 0.5% gelatin stabilizer. Overrun should be 70-80% to produce a good body. For the diabetic's convenience, the package should be labeled as to ingredients of the ice cream, explanation of the function of the ingredients and the total calories contained in the package.

W. H. Martin

750. Fruit puree expected to play greater role in ice cream sales. D. G. Sorber. Can. Dairy Ice Cream J., **29,** 7: 37-39. July, 1950.

The production of frozen fruit purees is a recent development in the fruit processing industry. The purees now on the market are apricot, banana, boysenberry, lemon, orange, nectarine, peach, plum, raspberry, strawberry and tangerine. Other purees can be made from apples, avocados, blackberries, loganberries, cantaloupes, cherries, cranberries, dates, feijoas, guavos, huckleberries, mangoes, passion fruit, persimmons and pineapple. The puree usually is added after defrosting at the freezer. A new frozen fruit dessert developed during the 2nd World War called Velva Fruit consists of fruit puree, sugar, gelatin and water. Sundae topping is another use for fruit purees. H. Pyenson

751. Lehigh Valley launches Duncan Hines ice cream. Anonymous. Ice Cream Trade J., **46,** 6: 30-32, 97. June, 1950.

The Lehigh Valley Cooperative Farmers of Allentown, Pa., have introduced a new deluxed pt. package of ice cream endorsed by Duncan Hines. Launched with promotional fanfare as an "Adventure in Good Eating", this ice cream contains 16% fat and low overrun with total solids slightly exceeding 42%. Within 2 wk., sales of the deluxe product equalled those of their standard pt. with no decrease in the sales of the standard pt. package. This quality product retails at 43¢ and the standard pt. at 26¢. W. H. Martin

752. Measured portion, rectangular factory-filled package makes a debut. Anonymous. Ice Cream Trade J., **46,** 6: 52, 91, 92. June, 1950.

A new, versatile package for use either for consumption off the dealers' premises or for "measured portion" use at the fountain has been developed. The carton, in 3.2-6 oz. size, has a spoon affixed and is designed for eating directly from the package. This is particularly adaptable to vending machine use. In this new carton, without a spoon, a fountain operator has ice cream measured to go in a soda, sundae or banana split and has uniform service and a controlled portion cost. Reports from users listed advantages of speed, economy and cleanliness.

W. H. Martin

753. Ice cream softener. M. C. Luterick (assignor to Diced Cream Co. of America). U. S. Patent 2,516,895. 3 claims. Aug. 1. 1950 Official Gaz. U. S. Pat Office, **637,** 1: 90. 1950.

Ice cream is softened by agitation in this device which consists of a rotating disc and several tines extending upward to form a basket-like agitator. The agitator fits into a container open at the top for loading and equipped with an outlet for drawing the softened ice cream. R. Whitaker

754. A study of sherbets and ices O. E. Ross, Natl. Pectin Prod. Co., Chicago, Ill., Ice Cream Trade J., **46,** 7: 44, 45, 86-92. July, 1950.

As the sugar content is increased the body and texture is improved, flavor more distinct and acid flavor less sharp. Approximately 26% total sugar produces proper dipping qualities and good flavor, body and texture. When 27% of the cane sugar is replaced by corn syrup solids, better body and texture are produced. Addition of homogenized milk so that the sherbet contains 2% fat and 5.2% m.s.n.f. reduces the intensity of fruit flavor and tartness and produces a desirable sherbet. Frozen fresh orange and lemon juices are superior to either fresh juices or extracts or emulsions of citrus fruits in making a satisfactory sherbet.

W. H. Martin

755. Newer methods in merchandising ice cream. Anonymous. Ice Cream Trade J., **46,** 7: 30-33, 99, 100. July, 1950

This Florida company has developed new methods in merchandising, plant procedure and distribution of packaged ice cream. A square pt. and 2 other packages, 1 containing 6 portions of vanilla, chocolate and strawberry and the other 20 portions, are manufactured. The ice cream is hardened, wrapped in corrugated board which then is wrapped and heat sealed in an attractive 4-color wax paper package in 1 complete, mechanical operation.

Attractive open display cabinets with colorful cards sealed in plastic were developed for use mainly in supermarkets to provide point-of-sale advertising for Velda-Plantation's trademarked name.

Insulated shipping containers of 50-gal. capacity on rollers were designed to provide easier handling for distribution. The latest equipment, including HTST pasteurization and a new automatic hardening machine, are housed in a beautiful, modern plant landscaped with tropical palms and flowers. W. H. Martin

756. Costing ice cream mix for the small dairy. A. Searles, Jr., Cornell's Dairy Prod., Endicott, N. Y. Milk Plant Monthly, **39,** 7: 40-42. July, 1950.

To itemize mix costs monthly profit and loss statements are made up. The first is a running inventory supply record of each ingredient in the mix excluding fat. The second is a mix manufacturing report on each batch of mix. The final statement is a summary of over-all costs including labor and overhead.

J. A. Meiser, Jr.

757. Costs of ice cream distribution. R. T. Smith, Scranton, Pa. Ice Cream Trade J., **46,** 6: 40, 41, 105. June, 1950.

The following are some of the trends ice cream distribution has been taking comparing 1949 with 1946 as based on a recent survey. Over 90% of the companies particapating in the survey deliver to 50% of their dealers 2 d./wk. and 75% deliver to 30% of their dealers 1 d./wk.; the remainder are on an every-other-day 3, 4, 5, or 6 d./wk. delivery. Since 1946, 75% of the companies reported that their truck capacity has increased 21%. They are selling 47% more items, including flavors, and they deliver to 14% more dealers with the average cost 50% more in 1949, as compared to 1946. W. H. Martin

Also see abs. no. 705, 717, 718, 719, 721, 722.

MILK AND CREAM

P. H. TRACY, SECTION EDITOR

758. Fortified skim with solids added. A. J. Ferm, Ferm Dairy, Rockford, Ill. Milk Dealer, **39,** 10: 42, 54. July, 1950.

The Ferm Dairy of Rockford, Ill., is selling a product known as "Ferm's Vita-Skim." In preparing the product, 2.5% of skim solids and 0.75% butterfat are added to the regular skim. It then is fortified with 2,000 units of vitamin A and 400 units of vitamin D. The local health department cooperated by publishing several articles regarding low-fat milk plus solids and vitamins. Sales of the product increased from 3,000 qt. in Feb., 1950, to 7,000 qt. in Apr., 1950. The Vita-Skim sells for 16¢/qt., while the homogenized and creamline sell for 18.5¢/qt.

C. J. Babcock

759. Supplementing fluid cream with frozen cream. H. V. Atherton. Can. Dairy Ice Cream J., **29,** 6: 62-64, 78. June, 1950.

Preliminary results indicate that frozen cream for use in a frozen cream-fresh cream mixture should be stored with 40% fat content rather than as 50% cream as is the storage practice for the ice cream industry. When 50% frozen cream is used for the mixture, a distinct skim layer is noted in the bottles. The frozen cream can be defrosted while the mixture is being heated to homogenizing temperature, slow defrosting of the cream producing no better results. 50% frozen and 50% fresh cream were used in this study. Best results were obtained using a homogenization temperature over 140°F. and a pressure of 100 lb./in.^{2} on a single-stage machine. The trials, conducted only on a laboratory basis, produce a satisfactory coffee and whipping cream. H. Pyenson

760. Shall I homogenize? R. F. HOLLAND, Cornell Univ., Ithaca, N. Y. Am. Milk Rev., **12:** 22, 24. Jan., 1950.

The decision to homogenize should be based on expected sales volume, influence of competition and profit margin. More problems are created than solved by adopting homogenization. Some of the problems are: (a) high equipment cost, (b) additional costs for power, gaskets, oil, repair, maintenance, depreciation, cleaning materials and labor, (c) control of leucocyte type of sediment even when milk is clarified, (d) control of off-flavors such as sunshine, flat or chalky and rancid, (e) possibility of high bacteria counts, (f) seepage of milk past the bottle cap and (g) utilization of route returns. D. J. Hankinson

761. Carton carrier. H. Z. GRAY. U. S. Patent 2,514,858. 7 claims. July 11, 1950. Official Gaz. U. S. Pat. Office, **636,** 2: 585. 1950.

A hand carrier for holding several cartons of the Pure-pak paper milk bottle type is described. R. Whitaker

762. A bottle cap contest. Anonymous. Milk Plant Monthly, **39,** 7: 68-69. July, 1950.

To promote milk and dairy products to children, a bottle cap contest for boys and girls under 15 yr. of age was staged. Running for 2 mo., the contest awarded 278 prizes to the contestants, top awards going to the 3 persons having the largest number of bottle caps. 533 youngsters entered the contest and 976,764 caps were returned. J. A. Meiser, Jr.

763. Incentives promote sales. F. FLAGG. Milk Plant Monthly, **39,** 8: 38-40. Aug., 1950.

To promote the sale of homogenized vitamin D milk, routeman were given a 30-d. period to persuade their customers to change over from regular milk. For every customer converted and held an additional 30 d., a bonus of 40¢/qt. was given. Year round contests are held on a monthly gain basis. Using the previous month's points as a base, routemen receive $1.00 for each point up to 10 and $1.50 for each point above 10. Safe driving is promoted by the management setting up a kitty which is divided at the end of 3 mo. to those drivers not having an accident. These contests not only lift the morale of sales personnel, but they provide a strong incentive force as well. J. A. Meiser, Jr.

764. Routeman's contacts build sales. Anonymous. Milk Plant Monthly, **39,** 6: 56-58. June, 1950.

Routemen receive $5.00 if they contact 30 prospects and $10.00 for 50 contacts, regardless of whether they become customers. Records of these calls are maintained on file cards at the plant. Delivery men also receive an additional bonus of $1.00 for every qt. of new business retained for 30 d. J. A. Meiser, Jr.

765. Postal cards bring new business. Anonymous. Milk Plant Monthly, **39,** 6: 68-69. June, 1950.

Penny postal cards distributed by routemen to customers request the name and address of friends, relatives or neighbors who may be interested in purchasing dairy products. These cards promote the sale of products, as well as providing the company with leads to prospective customers. J. A. Meiser, Jr.

766. New educational project for better understanding of the dairy industry. Anonymous. Milk Plant Monthly, **39,** 6: 60-61. June, 1950.

A new educational project known as a "Class Workit" has been prepared by Education Research, Inc, Washington, D. C., that will enable elementary students to assemble a 3-dimensional dairy plant in the classroom. With this model comes a supplement for teachers. Thus, the flow of milk from the farm through the plant processing equipment is fully explained. The project is not designed to replace plant visitation but to be used in conjunction with field trips. J. A. Meiser, Jr.

767. The cow—mankind's benefactress. E. B. ANDERSON, United Dairies, Ltd., Central Lab., London. Chem. Ind., **11,** 195-204. Mar., 1950.

A discussion of the synthesis and nutritional value of the constituents of milk is followed by a summarizing review of several physical, chemical, microbiological and manufacturing aspects of butter, cheese, condensed milks and dry milk solids. E. B. Collins

768. The dairy industry in Greece. S. A. KALOYEREAS, Agr. Expt, Sta., Louisiana State Univ., Baton Rouge. Natl. Butter & Cheese J., **41,** 3: 22-23, 49. Mar., 1950.

During the decade prior to the last war, the milk production in Greece was 555,000 tons. About half of the production was consumed fresh, the rest being made into butter and cheese. Butter production amounted to less than 5,000 tons annually. Though Greece exports some cheese (300 tons), its imports are more than twice its exports. Approximately 80% of the milk produced comes from sheep and goats. The per capita consumption of dairy products is low. An examina-

tion of the average Greek diet reveals it to be low in Ca and P. Annual per capita consumption of dairy products was as follows: 84 lb. of milk, 18 lb. of cheese, 1.57 lb. of butter. The milk industry is still in a primitive state of organization. Efficient milk producer cooperatives are needed. There also is a great need for modern equipment and technically trained personnel, as well as adequate sanitary regulations and composition standards. H. E. Calbert

769. New Zealand dairy. Anonymous. Milk Dealer, **39,** 10: 43-44, 105-106. July, 1950.

The city of Wellington, N. Z., established the municipal milk department in 1918 and became the first city to have a municipally-owned milk plant. More than 140,000 consumers were supplied daily in 1948. In addition to these consumers, schools were supplied with milk under a government program which called for 279,670 gal. in 1948–49. Total sales of milk in this period were the highest ever recorded and amounted to 8,770,353 gal. Of this total gallonage, 6,607,032 gal. or 84.89% were bottled. The plant operation, marginal costs, farmer price system and consumer prices are discussed. C. J. Babcock

770. F A O aiding European countries with equipment for milk production. N. E. Dodd. Can. Dairy Ice Cream J., **29,** 6: 74-78. June, 1950.

The Food and Agriculture Organization of the United Nations is installing new equipment in many countries of the world where adequate dairy plants are lacking. H. Pyenson

Also see abs. no. 713, 720, 730, 731, 733, 738.

SANITATION AND CLEANSING

K. G. WECKEL, SECTION EDITOR

771. Factors affecting activity of chemical germicides. C. K. Johns, Can. Dept. of Agr., Ottawa. Milk Plant Monthly, **39,** 5: 54-56, 58. May, 1950.

Factors affecting the activity of chemical germicides are type of compound, concentration, time of exposure, temperature, organic matter, pH, wetting ability, stability of product, type of organism, condition of the organism, number of organisms present, nature and physical condition of surface, incompatible compounds and residual film. Maximum sanitizing effectiveness may be obtained if one applies this information to his operation. J. A. Meiser, Jr.

772. Water and alkali required to wash milk bottles. P. S. Lucas, Mich. Agr. Expt. Sta., E. Lansing. Am. Milk Rev., **11,** 12: 44-45. Dec., 1949.

Studies on 1 bottle washer installation revealed that 0.86 gal. of soft water and 0.03 oz. of alkali were used to wash each qt. bottle or its equivalent. The water consumption rate should be useful in estimating water softening capacities for milk plants. D. J. Hankinson

773. The fieldman and the farmer's wife. Grace R. Duffee and H. E. Calbert, Univ. of Wis. Butter, Cheese & Milk Prod. J., **41,** 6: 23-24, 42-43. June, 1950.

Surveys indicate that the farm wife does a large share of the milking and cleaning of milk utensils on the average dairy farm. A dairy plant fieldman must get the cooperation of the farm wife before any milk quality program that he is instituting can become effective. The home demonstration agent from the County Agricultural Extension Office, by her influence over the farm women, can assist the dairy fieldman in making a milk quality program a success.

H. E. Calbert

774. A bug's eye view of dairy plant architecture. E. M. Searls, Natl. Dairy Products Co., Inc. Butter, Cheese & Milk Prod. J., **41,** 5: 32–33, 66-69. May, 1950.

An entomologist makes several suggestions to reduce the hazard of insect or rodent infestation when building or remodeling a dairy plant. Locate on side roads or rail tracks to avoid dust and dirt of heavy traffic. Rats and insects are more likely to be encountered when plants are located near lakes, rivers and centers of heavy population. Filtered air for ventilation, rather than air from open windows, reduces the chances of contamination by dirt, dust and insect fragments. Doors must be self-closing and be kept closed to be rodent proof. When false ceilings are used, they should be sealed off to keep out the dust and vermin. Some hiding places for such insects as roaches can be eliminated by setting electrical conduits and control boxes either flush with the wall and sealed or far enough away from the surface to permit easy cleaning. The fewer the conduits, pipes, etc. in the processing room, the less the number of hiding places for roaches and other insects. The storage of employees' lunches, cookies, etc. in lockers serves as an invitation to insects. Place lockers so that they can be cleaned on all sides and treated with insecticides.

H. E. Calbert

775. Insects and rodents must be stopped before they start. E. M. Searls, Natl. Dairy Prod.

Corp., N. Y. Am. Milk Rev., 12, 44-46. Jan., 1950.

The presence of insects or rodents is an index of sanitation. Effective control procedures should include (a) thorough clean-up of plant and outside areas, (b) effective screening and selfclosing devices for doors and tight passes for pipes and (c) use of effective residual type insecticides for insects and a systematic trapping program for rodents. D. J. Hankinson

Also see abs. no. 695.

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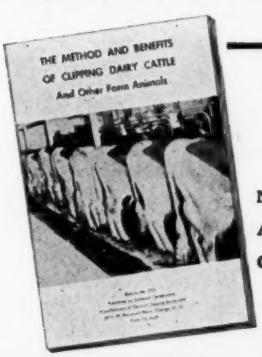

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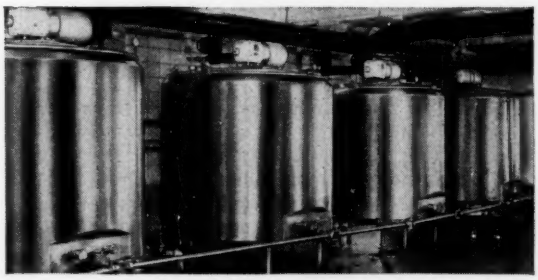

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